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AMERICAN WELDING SOCIETY
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JOURNAL

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ANNUAL MEETING AMERICAN BUREAU OF WELDING

The present age has been rightfully called the age of research. Glancing through the annual report of one of the largest companies in this country, namely the American Telephone & Telegraph Company, we learn that the present demands of telephone communication could only be met through the results of the research efforts of hundreds of scientists who devote all of their time to scientific studies.

Welding has emerged during the past ten years from an obscure process which was used with more or less success as a repair tool to one of the foremost mechanical processes today. This cycle of development has in a large measure been brought about through the application of research methods.

Although rapid progress has been made still the fundamental reasons underlying the several processes of welding are not as yet understood. The problems are so complex that the combined wisdom of many workers is needed for their solution. The annual meeting of the American Bureau of Welding will be devoted very largely to the presentation of some of the outstanding problems and methods proposed for their solution by several experts. A limited number of executives of leading companies interested in welding have been invited to attend this meeting. It is expected that as a result of the discussion the Bureau will be in a position to undertake a comprehensive coordinated program of investigation which will materially advance the welding art and extend its application to new fields.

DINNER DANCE

The 1926 Dinner Committee have made strenuous efforts to make this event an outstanding one in the history of the American Welding Society and one that will be long remembered. The Rose Room of the Hotel Astor has been chosen as the place and the management has assured us that a first-class dinner will be served. A variety of very interesting and novel features have been provided in the way of entertainment, including high-class professional talent, a five-piece orchestra for dancing and incidental singing. In addition, there will be "stunts" on the wonders that can be accomplished by liquid oxygen.

There will be very little speaking and the combination of an excellent dinner, entertainment, agreeable surroundings and a dance assures everyone who attends an enjoyable evening which cannot be surpassed even though several times the amount of admission were paid.

The members of the Society are now called upon to contribute their share to the success of the first event of this kind in the history of the American Welding Society by attending and bringing their friends, sweethearts, daughters and wives. Tickets are $6 per person and reservation should be made at once by writing to the secretary of the Society. Checks may accompany these reservations.

INTERCHANGE OF INFORMATION

The national Meetings and Papers Committee is pleased to report that this year it has been able to arrange with prominent welding experts of the East to present timely papers on various phases of welding before the Sections on the Western Coast. Among these speakers are included A. G. Bissell, Westinghouse Electric & Manufacturing Co.; S. W. Miller, Union Carbide and Carbon Research Laboratories; D. H. Deyoe, General Electric Company, and J. F. Lincoln, of the Lincoln Electric Co. Every effort will be made to continue such arrangements in order that continuous interchange of information may be provided. Prominent speakers from the Western Coast will be induced whenever possible to present papers before our Sections in the East.

DISCUSSION OF PAPERS

In this Journal there are printed a number of the papers which will be presented at the annual meeting of the American Welding Society. Each author will be allowed a few minutes to present the high spots of these papers, after which the meeting will be thrown open for discussion.

If you have any experience or information in any field of welding bearing on the subject of proper design of welded joints, you are earnestly requested to attend this meeting and to participate in the discussion. If there are any points not fully covered in these papers concerning which you desire additional facts, questions may be asked at the meetings and the authors will endeavor to make these points clear.

COMMUNICATION FROM BUFFALO CHAMBER OF COMMERCE

To the Members of the American Welding Society:

We want to go on record with the statement that we not only feel highly honored, but that words are unable to describe how pleased we are that the American Welding Society has selected Buffalo as their meeting place for this year. When I say we are pleased I mean every word of it, because we are going to jump right into the harness with your local committee to help make the Buffalo meeting the most successful in the history of your organization.

We feel confident in saying that the attendance at this meeting from November 16th to the 19th, at which time you will have the International Welding and Cutting Exposition, will surpass anything that you have ever had and will be a goal to shoot for in the future.

The Broadway Auditorium, with 47,000 square feet of unobstructed floor space, will house your exposition, and if the enthusiasm and plans, plus the hard work your committee has started out with is any criterion to go by, you have our assurance that you will make no mistake in drawing a circle around the 16th to the 19th of November next and inserting the words "I am in Buffalo."

In our humble estimation no better selection could have been made than Buffalo, which city can be reached by over 65 per cent of the population of the United States and 80 per cent of the population of Canada in no more than a one night's train run. There has never been a more opportune time to preach the gospel of the welding industry and what it stands for than at this year's meeting and it can only be done through 100 per cent attendance on the part of yourself and the other members of the American Welding Society.

Can we depend upon your being here?

W. T. BUCKLEY,
Convention Manager.

BOUND VOLUMES OF JOURNAL

The standing orders for bound volumes of the Journal having been filled, the Society now offers the few remaining copies of the bound volumes for the years 1922-23-24-25 for general sale to the members at $5 per copy and to non-members at $10 per copy.

Each volume contains subject and authors index in order that information on specific subjects may be readily accessible for reference. Undoubtedly the best welding information now in existence is included in these issues. The results of many thousands of dollars of research investigations are incorporated in many of the reports of the American Bureau of Welding and of private corporations. The bibliography of current welding literature given in each issue is a complete bibliography of all the important welding articles appearing in other journals here and abroad.

INSPECTION TRIP

Everyone connected with the welding industry has often wondered how Thermit is made and what steps are necessary in the process of manufacture. Some have been fortunate enough to see how Thermit welds are made, while others have not had an opportunity to see a mixture of Thermit turned into highly superheated molten steel in a fraction of a minute. All of these wonders will be seen during the inspection trip of the American Welding Society on Friday afternoon, April 23.

Buses have been provided through the courtesy of the Metal & Thermit Corporation which will pick up the members of the Society at the Hudson Tubes Station, Journal Square, Jersey City, and transport them to the plant of the company. The buses

will start promptly at 2 o'clock from the station in order that sufficient time may be allowed to make a thorough examination of the plant. Those arriving late will be obliged to provide their own transportation. Reservations should be made in advance by writing to the secretary of the So-

SECTION ACTIVITIES

Western New York

Prof. A. S. Kinsey presented an address at the Feb. 26 meeting on "Engineering Value of the Joining of Metals." The next meeting of the Section will be held on Friday evening, March 26, at the Hotel Statler. S. W. Miller will present a paper on "Oxy-Acetylene Welding of Copper."

Pittsburgh

The February meeting was held on the 12th, at which S. W. Miller, consulting engineer, Union Carbide and Carbon Research Laboratories, presented a paper on "Oxy-Acetylene Welding of Copper."

Chicago

The March meeting was held on the 5th. A motion picture entitled "From Mine to Consumer" and an address on the subject of bronze welding were presented by the American Brass Co.

Boston

The March meeting was held on March 19th at Franklin Union, Boston, with an attendance of about 100. A very interesting and instructive lecture by A. G. Bissell of the Westinghouse Electric & Manufacturing Co. on "Welded Structures," illustrated by lantern slides, was given. Informal discussion followed on different welding operations.

San Francisco

A meeting of the Section was held on March 19th, at which time D. H. Deyoe, engineer of the Industrial and Engineering Department of the General Electric Co., Schenectady, presented a review of automatic welding and welding in a gaseous atmosphere.

EMPLOYMENT SERVICE BULLETIN

POSITIONS VACANT

V-31. Salesmen and Estimator wanted. Required by one of the largest and best established job welding concerns in New York. Preferably a man who has experience or one who has a fair knowledge of welding, both gas and arc, and who is accustomed to doing business with large service stations and fleet owners.

An interesting proposition will be made to the right man, which assures a good income on a salary and commission basis, to a live wire who can produce. All details will be treated in confidence.

V-32. Experienced welder or welding engineer wanted who has had broad experience in tank welding including bath boiler construction. In our Seamless Division we have decided to develop welding of certain types and styles of containers, and we want experienced man to follow work through various stages including testing.

V-33. Welder wanted with experience in electric arc and oxy-acetylene welding.

Services Available

A-41. Electric welder desires position. Have had 8 years' experience, including repair, machine and boiler work on the Erie R. R. and high pressure vessel and tank work of Standard Oil Co.

A-42. Electric welder desires position. Have had 10 years' experience, including six with the Tide Water Oil Co., three years with Standard Oil and one and one-half years with M. W. Kellogg Co.

A-43. Oxy-acetylene welder desires position. Have had five years' experience and can weld any kind of work, including aluminum.

A-44. Acetylene welder desires position. Have had seven years' railroad shop welding experience and four years' industrial welding. Desire position as Foreman or Supervisor. Have credentials as welder, also as instructor.

A-45. Oxy-acetylene welder desires position. Have had experience and can furnish reference.

Welding in the Design of Industrial and Power Piping*

L. J. SFORZINI†

Fusion welding and cutting of steel and wrought iron in the field of power and industrial piping, has recently acquired great momentum. The importance of welding in the piping field, and the sole reason for its use at all, is due to the fact that in certain specific instances, its employment yields the greatest return per dollar invested in the piping system and in the equipment of which the piping is a part.

The greatest return does not necessarily signify that the first cost must be least; but it means that over a period of years, every possible factor being considered, the return is greatest. The factors to be considered are: life of the equipment and piping system; safety; ease of operation, and saving in operation; space occupied, and continuity of operation, as well as cost for the complete system.

Perhaps it is not generally known to the members of the Society, as it is to the industrial plant and power engineer, that perfection in welding methods is one of the most important factors in the placing of the production of heat, refrigeration, and industrial power on the "mass production basis" so characteristic of American methods. Most of us are familiar with the layout of the average large industrial plant. The plant is generally laid out in groups of buildings, so situated as to make handling of the materials that go into the finished product to be manufactured a minimum. Only a few years since, if heat processes were involved, each of these groups was served by a separate steam plant located at its center. At the present time, however, it is customary to provide only one steam and power plant to serve the entire industrial plant, regardless of area covered, and production of heat and power are concentrated, eliminating duplication of effort and supervision, lessening the duplication of equipment, and making possible the employment of larger and more efficient units. These results lead to lower costs in the heat and power departments, which, of course, are reflected in the lowered cost of the finished product.

In certain industries the production of heat and power is considered by the management to be a necessary evil that goes with the manufacture of their own particular product. Were it possible to turn over the production of heat and power to specialists, the local utilities, at a reasonable figure, the managements would gladly do so. Electricity, of course, can be transmitted over practically any distance, but until quite recently the transmission of heat in its usual form of steam was considered impracticable over

*To be presented at annual meeting, A. W. S., April, 1926.
†Engineering and maintenance department, Kodak Park, Rochester, N. Y.

any but limited distances. This made it necessary for all industrial plants to have a steam plant for heat processes and heating. Steam and electricity go hand in hand; where steam is produced it usually pays to also generate electricity to some extent.

Power, June 14, 1921, and *Power Plant Engineering*, Feb. 1, 1921, both show how two important Dayton, Ohio, industries, located some distance apart and both owned by the same management, turned over the production of their steam to the local utility, even though it meant the construction of a total of 3575 ft. of steam main underground through the public streets of Dayton. There are 1145 ft. of 14-in., 1321 ft. of 12-in. and 1109 ft. of 10-in. pipe. On this entire length not one single flanged joint was used. The electric arc process was used for the 274 welds, which were made of the V butt weld type. The pipe used was extra heavy and sleeve type expansion joints were used, and 175 lb. pressure is carried. The use of welding made this project commercially practical.

At the time the above installation was made, a high pressure steam main of this size was considered quite an engineering feat. Today mains 2000 ft. long are common. The writer participated in the design of a 4800 ft. 12-in. main with 225 lb. working pressure, where all the steam is normally transmitted from one end of the main to the other.

Having thus stated the reasons for the existence and importance of welding in the industrial and power field, we can now proceed to show where, how and why welding can be used to advantage. The author is not of the opinion that everything, or a major portion of everything, in a piping system should be welded to the exclusion of all other methods; but he is of the opinion that every piping system should be studied by itself to determine if welding can be used to advantage. Power and industrial piping can broadly be classified thus:

PIPE CLASSIFICATION

I. High Pressure Steam Piping

II. Low Pressure Steam Piping

III. Refrigerating Fluid Piping
- (a) High pressure ammonia piping
- (b) Low pressure ammonia piping
- (c) Brine piping

IV. Air Piping
- (a) Piping under compressor pressure
- (b) Piping under blower pressure

V. Water Piping
- (a) Hot water
- (b) Cold water

VI. General Fluid Piping

Each of these will be studied in detail under a separate heading, but before proceeding with this study, let us investigate the ordinary non-welded joints and point out both their advantages and disadvantages, so that we may properly understand what is required of welded joints. There are four principal types of joints,

other than the welded joint, used in pipe work. These are depicted in Fig. I and are (a) the threaded joint; (b) the Vanstone joint; (c) the integral joint obtained by forging or casting, depending on whether the pipe is wrought steel, cast steel or cast iron; (d) the riveted joint. In addition to these there are the various types of shrink joints and other forms of riveted joints.

The screw thread joint is still the most extensively used pipe joint and will probably always continue to be the most common joint. The illustration shows the flange joint, but this is only one

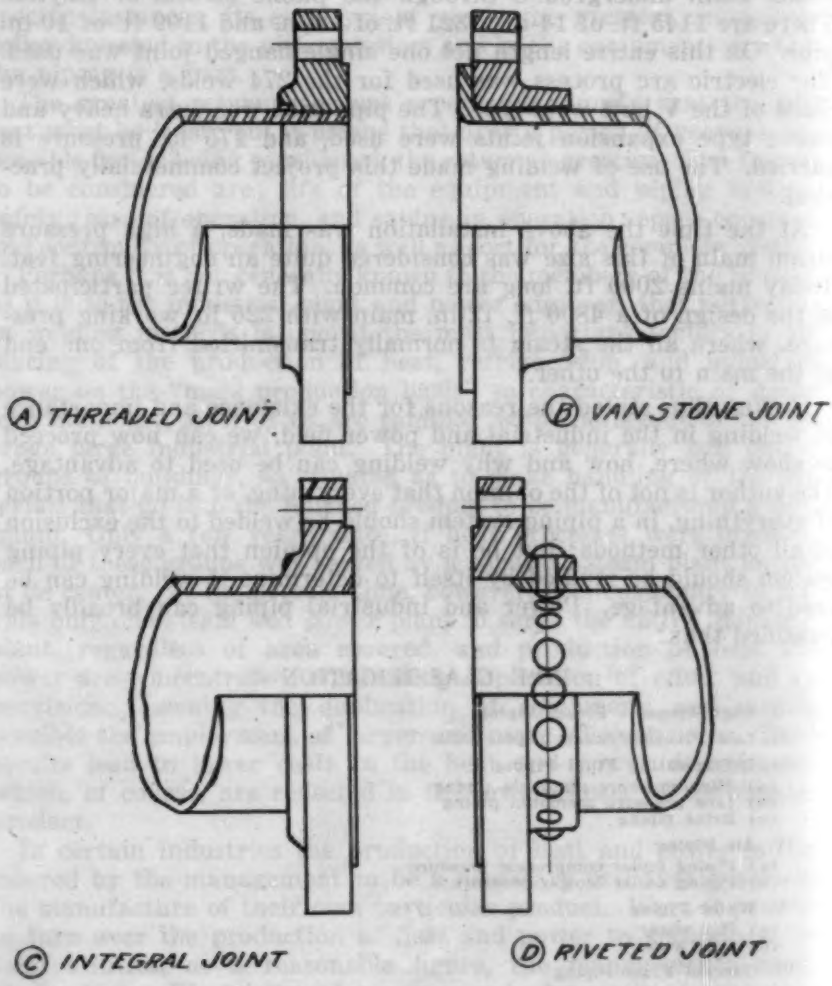


Fig. 1

form of the screw joint. For the small pipe sizes and ordinary work the flange is rarely used for sizes below 2½ in.; instead, in line joints a screwed coupling is used, for fitting joints the pipe screws

directly into the fitting or valve, and the final joint in a closed path is made with a pipe union. The screw joint is comparatively easy and cheap to make in the smaller pipe sizes with simple hand tools, and for low pressure fluids is very satisfactory in these sizes. As the pipe sizes increase hand tools become more expensive, more labor is required for making up the joint, until for certain sizes nothing but power machinery will suffice to make up the joint.

The bulk of all pipe work is done on the smaller pipe sizes; so it does not, as a rule, pay to invest in a power machine unless the quantity of big work to be done is large. The heavy power machines are

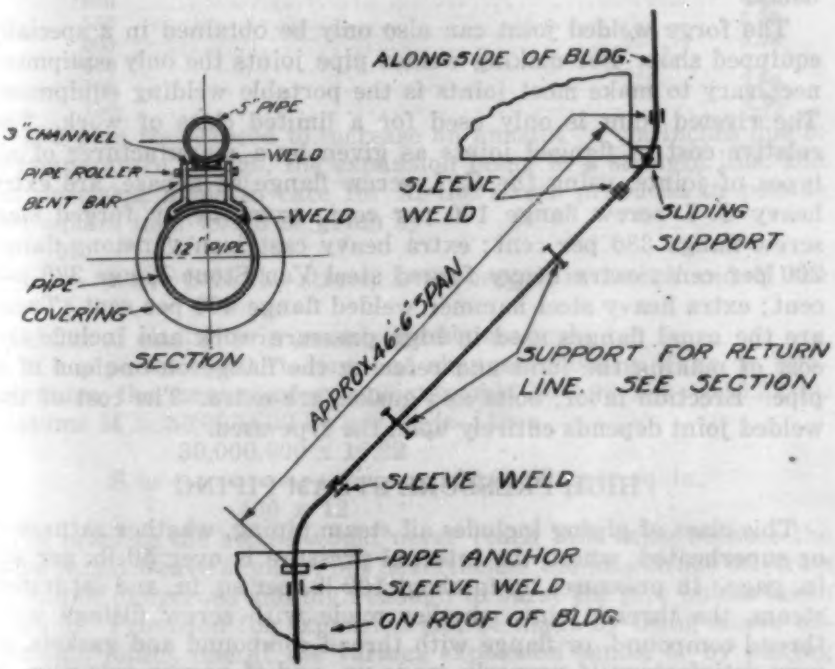


Fig. 2. 12 in. welded steam line supporting 5 in. water line across large span

expensive, so that only large jobbing shops can afford the equipment to make the very large threaded joints. The average pipe shop is only equipped to thread up to 8 in.; the large shops up to 12 in., and only the very large shops are equipped to handle up to 18 in. or 24 in. diameter, the last of which is the largest commercial thread size. In our own industrial city of 325,000 the largest pipe machine can handle nothing larger than 18 in. pipe, and this was only installed 3 years ago.

The vanstone joint is purely a manufactured joint and cannot be made by the ordinary pipe user, but must be purchased from the piping fabricator equipped with special machinery adapted to this class of work. This involves purchasing the pipe to definite dimen-

sions for field erection. The closing piece in a pipe run with this type of joint presents complications: The piping can, of course, be laid out and carefully figured and the closing piece ordered to the proper length with the rest of the piping; but in practice this does not always work out so well, because sometimes things happen to upset the most accurate of calculations. A valve as purchased might be of a different make than planned on, slight discrepancies might be cumulative, and a host of other things may happen. Another method is to take the dimensions when everything is in place, insert the final piece, and then specify the length, but this involves delay.

The forge welded joint can also only be obtained in a specially equipped shop. For making welded pipe joints the only equipment necessary to make most joints is the portable welding equipment. The riveted joint is only used for a limited class of work. The relative cost of flanged joints as given by a manufacturer of all types of joints, using the C. I. screw flange as a base, are extra heavy C. I. screw flange 100 per cent; extra heavy forged steel screw flange 380 per cent; extra heavy cast iron vanstone flange 200 per cent; extra heavy forged steel Van Stone flange 380 per cent; extra heavy steel hammer welded flange 400 per cent. These are the usual flanges used in high pressure work and include the cost of making the joint and refacing the flange on one end of a pipe. Erection labor, bolts and gasket are extra. The cost of the welded joint depends entirely upon the type used.

HIGH PRESSURE STEAM PIPING

This class of piping includes all steam piping, whether saturated or superheated, where the internal pressure is over 50 lb. per sq. in. gage. In pressures up to about 100 lb. per sq. in. and saturated steam, the thread joint, whether made with screw fittings with thread compound, or flange with thread compound and gaskets, is very satisfactory if properly made up, and if proper provision is made for support and expansion. Above 100 lb. per sq. in. pressure, with or without superheat, the threaded joint in the larger pipe sizes begins to give trouble. But the Van Stone joint, properly made up and with proper gaskets, with proper provision for support and expansion strains, gives satisfactory service up to pressures of about 300 lb. per sq. in.

Steam piping, especially high pressure steam piping, differs from other piping in that it contains a gas at a high temperature. When the pipe line is installed the line is cold; when the pipe line is placed in service it becomes hot. This change in temperature causes expansion, which in turn produces stresses in the pipe line, unless the expansion is provided for. This provision must be made whether the line is installed with screw flange, Van Stone flange or welded joints. The amount of pipe expansion in inches per hundred feet

for various temperature changes in steel pipe is given in the following table:

Temperature, Change, Deg. Fahr.	Expansion in Inches
0	0.00
50	0.38
100	0.76
150	1.15
200	1.57
250	1.99
300	2.47
350	2.94
400	3.46
450	4.08
500	4.67
550	5.30
600	5.98
650	6.71
700	7.50
750	8.36

If a pipe was caused to increase an amount "e" in inches due to a temperature change, the expansion being in a straight line, and no provision made to care for it, the stress produced in pounds per square inch would be given by

$S = \frac{Me}{L}$ where S is the stress, L the length in inches and M the modulus of elasticity in pounds per square inch.

If a pipe were 400 ft. long and changed 450 deg. Fahr. in temperature, the amount of expansion would be 4.08 x 4 = 16.32 in. Assume M = 30,000,000 lb. per sq. in.; then

$$S = \frac{30{,}000{,}000 \times 16.32}{400 \times 12} = 102{,}000 \text{ lb. per sq. in.}$$

In practice the stress would never reach this value because the pipe would weave slightly, but nevertheless the magnitude of stress would be dangerous and high enough to burst the pipe unless taken care of. Provision for expansion can be made by using sleeve expansion joints, one of the various expansion bends, or by placing turns in the piping system. A sleeve expansion joint gives no temperature stress if no binding action in the sleeve part takes place. However, most engineers are reluctant to use sleeve expansion joints, because they invariably leak if circumstances are the least unfavorable to them, although there are some very improved pipes now on the market. Bends or turns in the pipe produce stresses. These stresses should be kept within the safe working stress of pipe material. The formulas now used for this purpose are those of Sabin and Crocker, arrived at from theoretical considerations and checked by actual experiment. See Transactions of A. S. M. E. 1922.

If an ordinary pipe line with C. I. screwed flanges used for saturated steam service has its temperature raised by adding super-heat to the steam, the gaskets invariably leak. The author observed one 8-in. steam line of this nature where the temperature was raised

approximately 90 deg. Fahr. by adding super-heat while the pressure was kept constant at about 135 lb. per sq. in. The line had been in service practically continuously for ten years without trouble of any kind, but within a month's time after the change was made, about one-half of the 30 joints in the line showed leaks.

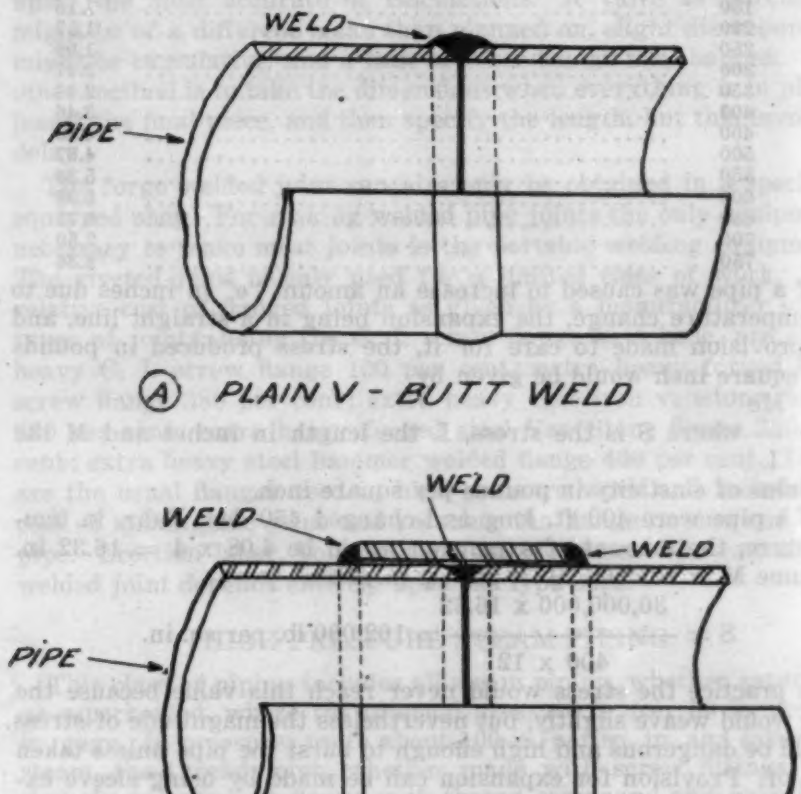


Fig. 3

Renewing the gaskets for a time remedied the trouble, but the new gaskets eventually also became leaky.

When a pipe line is continuous over a number of supports with a flanged joint midway between two supports, a strain is set up at the joint due to unequal stress at bottom and top of the flange. For cast iron flanges this strain might break the flanges if the span is sufficiently great; for cast iron or steel flanges made up with screw threads or Van Stoned and with bolts and gaskets it might mean a

leak for large spans. That the behavior of welded joints, under the most adverse conditions of this kind, might be judged, Fig. II was drawn. It was necessary to span between the two buildings at a point about 25 ft. above the street level. Note that the buildings are offset from each other, causing the pipe to cross at approximately a 45 deg. angle, the clear span between supports was approximately 46 ft. 6 in., and the pipe curved after leaving each support. The pipe used was full weight standard 12-in. pipe and was installed

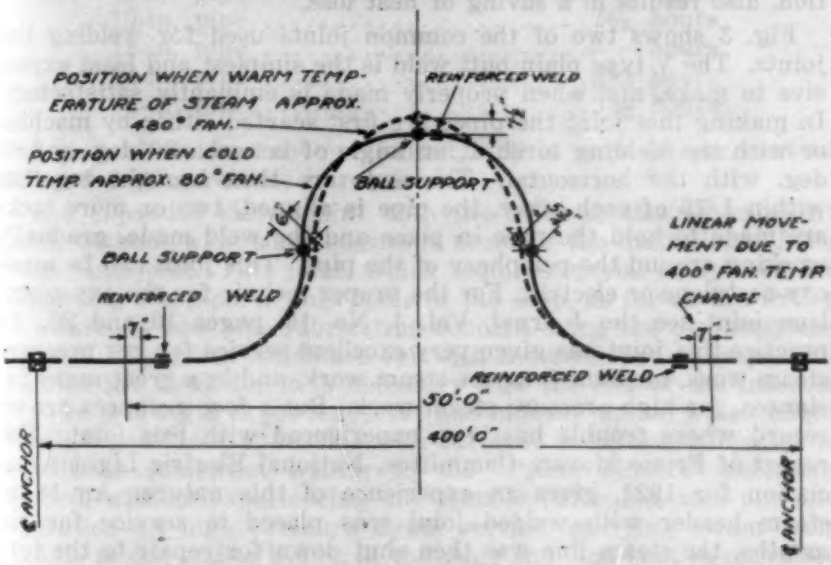


Fig. 4. Actual movement in a 12 in. expansion U-bend under steam temperature

for steam service at about 175 lb. pressure and superheat. Also note the position of the welds, which are of the combination butt welds, sleeve type made oxy-acetylene, two below on the ground and the other two with the pipe in place. After the line was in place, it was used as a support for a 5-in. line filled with water, as shown in the cross section. The 5-in. line was supported as shown with steel supports welded to the 12-in. line. There is a combination deflection in the 12-in. pipe due to its own weight plus that due to the water line and that due to expansion. Any type of flanged pipe would have required an expensive bridge.

From what has been said, it is at once apparent that unless extreme care is used in the piping design and installation, gaskets are a source of trouble which might or might not be serious. Gasket elimination opens up an important field for welding.

Steam piping when charged radiates heat to the atmosphere when bare. Pipe covering eliminates the greater portion of this heat loss. As an investment, pipe covering gives good return. As a rule the covering of flanges, particularly on high pressure steam lines, also gives a good return on the investment, but not as big a return as on plain pipe because the labor expense is greater. Cov-

ered flanges still lose a certain percentage of their heat. Theoretically, an infinite thickness of insulation is required for 100 per cent efficiency, but, practically, the flange insulation is made the same as that of the pipe to which it is attached. In *Power*, Nov. 20, 1923, page 798, or National Tube Bulletin No. 10, the present writer works out the saving in one actual welded line as 35 tons of coal per year, over a line with the same number of flanges as welds. So gasket elimination, which goes hand in hand with flange elimination, also results in a saving of heat loss.

Fig. 3 shows two of the common joints used for welding line joints. The V type plain butt weld is the simplest and least expensive to make, and when properly made is eminently satisfactory. In making this joint the pipes are first scarfed either by machine or with the welding torch at an angle of between 30 deg. and 45 deg. with the horizontal. The ends are then brought together within 1/16 of each other, the pipe is aligned, two or more tacks are made to hold the pipe in place and the weld made, gradually working around the periphery of the pipe. This joint can be made oxy-acetylene or electric. For the proper technic for the oxy-acetylene joint see the Journal, Vol. 4, No. 10, pages 19 and 20. In practice this joint has given very excellent service for low pressure steam work, medium pressure steam work, and in a great many instances, for high pressure steam work. But a few instances are on record where trouble has been experienced with this joint. The report of Prime Movers Committee, National Electric Light Association for 1921, gives an experience of this nature. An 18-in. steam header with welded joint was placed in service for six months, the steam line was then shut down for repair to the turbine lasting two months. An attempt was then made to place the line in service, when a small by-pass valve was opened to warm up the line a leak was discovered in the line, and examination revealed the fact that one joint had opened up all around the pipe. Further examination revealed that no bond existed between the weld metal and the joint. Hydraulic and impast tests on all the rest of the welded piping proved this to be the only joint affected.

The butt weld reinforced with a sleeve or band overcomes the objections that some engineers have to the plain butt weld joint. This joint gives a double seal against bursting pressures, a double seal against leakage, and a double insurance against tensile and compressive stresses parallel to the pipe axis. This joint can be made with either the oxy-acetylene or electric processes. The sleeve slipped over the butt weld is placed on the pipe before the pipe is brought together and has 1/16 in. to 5/32 in. clearance over the pipe. Ordinary screw thread pipe couplings are satisfactory for this work; all that is necessary is to machine the thread off in a lathe. In welding the sleeves best results are obtained by the use of two welders each on opposite ends of the sleeve; this avoids expansion strains in the weld. The writer has taken some observations in the field of time required to make up this joint by pipe

welding specialists in the employ of one of the large piping fabricators and erectors using the oxy-acetylene process. The time includes all time from the time the pipe is aligned to the time when the sleeve is completely welded on, and is computed on a one man basis. The pipe is all standard full weight. The results are given in the following table:

6-in. pipe	2¼ hours
8-in. pipe	2½ hours
10-in. pipe	2¾ hours
12-in. pipe	3 hours
14-in. pipe	3¼ hours
16-in. pipe	3½ hours

For general welders not specialized in this work 50 per cent to 100 per cent more time is required.

The expanded sleeve joint with the holes is also an excellent joint, without what some engineers consider the limitations of the plain butt joint. This joint, which requires special equipment for expanding the pipe, is only made in the shop, as far as the writer is aware, by one pipe fabricating concern using the oxy-acetylene process. The holes which are cut with the torch are an important part of the weld, for it is necessary that the end of the inserted pipe be held rigid to prevent lever and moment action which might break the weld. A 12-in. line with 217 such welds was subjected to conditions somewhat similar to the "Prime Movers" reference quoted, without experiencing any trouble. This line was put into operation on high pressure steam service, carrying steam from 215 lb. at one end to 150 lb. at the other end, and kept in operation with moderate superheat continuously for 18 months. At the end of this time it was shut down for a period of three days and permitted to become cold, after which it was placed in service again without any trouble developing.

That the Society can appreciate that the expansion in a steam line is actual as well as theoretical Fig. 4 is drawn. This is based on actual measurement taken by the writer on this line when warm, when cold and when warmed again. During installation the bend was put in under tension pulling the bend apart an amount equal to half the pipe movement. It might be well to note here that every point of the expansion U bends in the line assumed the original warm position after being rewarmed. There was no additional growth. The bend was installed in a horizontal plane. Note, particularly, that there is a sleeve joint made in field at the end of the U which is near the point of maximum stress.

The 217 welds mentioned some of which are field and some shop, are for only a part of the complete steam line.

The whole line contains 4815 ft. of 12-in. pipe, and in addtion to the welds mentioned there are 23 butt welds reinforced with sleeves and 9 welded necks. Most of the welds were made by welders in the employ of the large fabricators and erectors, but a few were

made by the general welders connected with the shop maintenance and construction force.

Fig. 5 was first published in *Power*, Nov. 20, 1923, by the writer, but is so good an example of the economical design possible with welding even in a short length of pipe, that he feels he will be pardoned for repetition. Fig. 5a shows how the installation would have been made according to the old methods with extra heavy cast fittings and Van Stone pipe. This was for an alteration job with

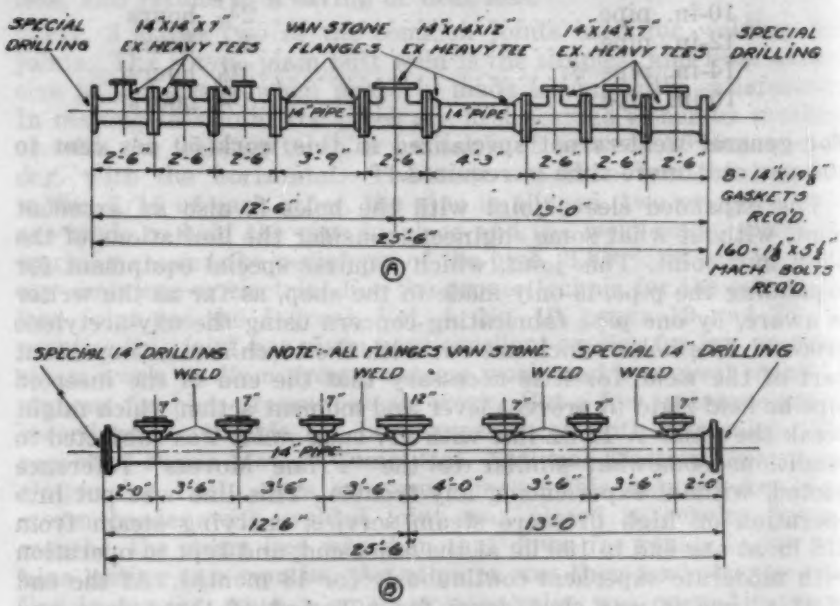
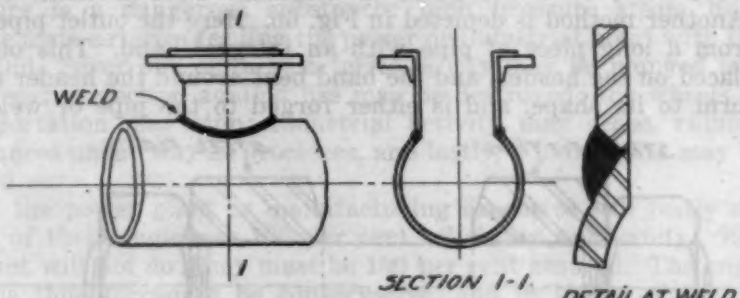


Fig. 5A. Alternate header made up with extra heavy fittings and pipe
Fig. 5B. Header with welded van stone outlet as installed

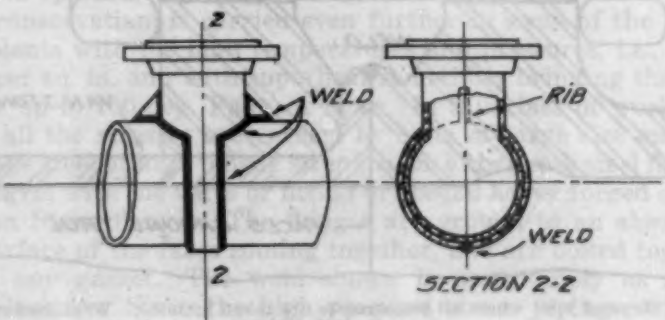
the face to face dimension, and the location of the 12-in. outlet from these faces fixed by existing construction. The drilling on the two end flanges was special, going against flanges no longer standard. The rest of the dimensions were variable within reasonable limits, except that the outlet sizes were fixed at 7 in. This header was intended for service at 225 lb. pressure. Note particularly the number of joints, bolts and gaskets required with this layout. Fig. 5b gives the alternate layout as actually installed. Time was a vital element on this job, as the installation could only be made at the expense of a plant shutdown, and the only shutdown period available was to occur very soon. The entire job was fabricated and shipped by a general pipe fabricating concern in about a week after receipt of order. The entire cost of purchased material and installation labor was but a very small fractional part of that estimated for the alternative layout. The particular welded header is the most perfect specimen of workmanship in pipe work that it has ever been the writer's privilege to view. The flange faces were all parallel or at right angles to one another and to the

pipe axis, the dimensions were all correct within very close limits, the neck welds were perfect and to the proper contour; no fins protruded into the pipe. That this piece could have been made so accurately and at such a low price, certainly indicates that the pipe fabricators thoroughly understand the possibilities of welding, and are completely equipped for economical production.

The welds previously described were for the elimination of pipe flanges in line joints; in the example described above welding was



A: Plain butt weld neck



B: Neck reinforced by hand

Fig. 6

used to eliminate fitting flanges. As in line welds the most elemental weld is the plain right angle butt joint (see Fig. 6a). This weld is made by using a piece of pipe with either a screw, Van Stone, integral or other flange on one end, with the other end plain and welding the plain end to the header at a point where a hole had previously been cut with the cutting torch. Either the oxy-acetylene or electric weld may be used. The usual method is to weld on the outside after scarfing the outlet pipe; but sometimes the weld is made both outside and also on the inside as a reinforcement. Where the outlet is small in size relative to the header, square ends are satisfactory. Where the outlets are large and closely approach the header in size, it is necessary to burn the outlet to a shape corresponding to the header contour. This can be done by the methods of simple descriptive geometry. In cutting the hole in the header, the outlet piece is used as a templet, the whole chalked

or scribed off and the cutting torch used to burn the hole, making proper allowance for fit. In using outlets or necks of this nature, the smaller the diameter of outlet the stronger is the resulting job. The writer prefers to use an outlet at least one pipe size smaller than the header for high pressure work.

Just as methods have been developed for reinforcing line welds, so have methods been developed for strengthening outlets or necks. One of the oldest and most satisfactory is the "interlock" weld, see *Power*, Nov. 20, 1923, or National Tube Bulletin No. 10. Another method is depicted in Fig. 6b. Here the outlet pipe is cut from a long piece of pipe with an integral band. This outlet is placed on the header, and the band bent around the header to conform to its shape, and is either forged to the pipe or welded or

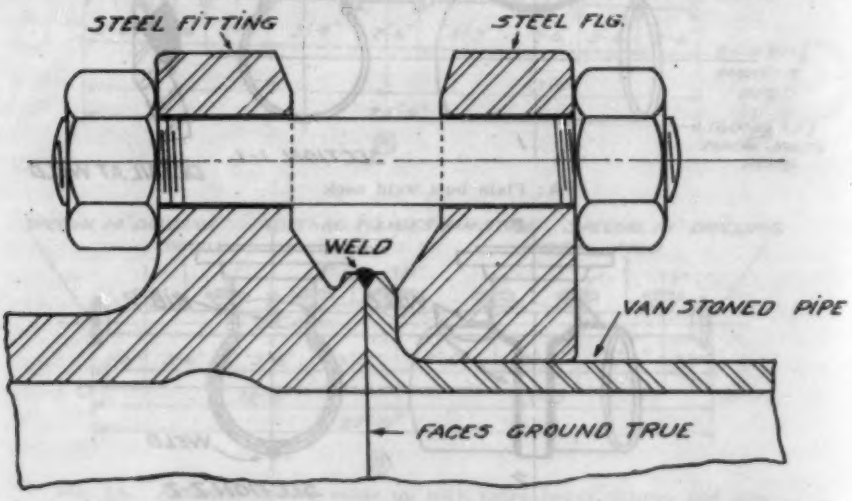


Fig. 7. Type of joint where all cell stresses are taken by bolts. Weld used only as seal against leakage

both, the outlet being welded in the usual manner. The reinforcing ribs are sometimes welded to the outlets, and may either be used in conjunction with the band shown or alone.

It may seem to some that these elaborate details on both the necks and line welds are both costly and unnecessary. How can we consistently advocate the welding of non-fired pressure vessels, which involves a joint with a plain V-butt weld, and yet turn around and say that this joint is not safe enough for simple tubular pipes? The reason for the additional requirement is because in addition to the stresses set up by the bursting pressure, there are certain, sometimes more important, stresses set up by expansive strains. Pressure vessels, even if heated, are comparatively short. Pipes are usually long and the amount of expansion is directly proportional to length. Until the classical research work of Sabin and Crocker, the importance of which is just beginning to be appreciated by the piping engineers, each designer had his own theory as to the magnitude of the stress produced by expansion bends and

turns. And oftentimes, in fact more often, no attention was paid to this stress at all, a bend was merely chosen for its supposed expansion value. The writer knows that there are certain large and important pipe fabricators that advocate the plain butt V-weld alone for high pressure steam work, and he personally would take the work of certain of these and safely figure, after proper tests on the completed line, that it would be safe to operate these lines under pressure to a certain definite maximum. Steam under high pressure is a dangerous substance; high pressure steam lines are the main arteries feeding the power or industrial plant with the life fluid. Sever one of these arteries, a city may be plunged into darkness; protection against fire may be destroyed; the wheels of transportation may stop; industrial activity may cease, ruining substances under way in processes, and lastly, a human life may be blotted out.

Yet the power plant or manufacturing executive will justly demand of their engineers 100 per cent reliability and safety. 99.9 per cent will not do; they must be 100 per cent assured. The engineer is thus forced to be conservative, and in steam piping he sometimes specifies the reinforced joints.

This conservatism is carried even further in some of the newer power plants with the high temperatures and pressures, i.e., above 300 lb. per sq. in. and with superheat sometimes bringing the temperature up to 700 deg. Fahr. or more. In this class of work (see Fig. 7) all the stresses are carried by bolts of large size made of high grade steel of high tensile strength, on either cast steel flanges, cast integral with the valve or fitting or special heavy forged or cast steel Van Stone flanges. The flanges are ground to an absolutely plane surface of the faces coming together, and are bolted together without any gasket. The weld shown is used simply as a seal against leakage. Since the high pressure steam piping cost of a large modern central station is but a very small part of the total investment, and since continuity of operation is dependent on absolute steam piping integrity, this expensive construction is here justified, just as the cost of standby units are justified.

LOW PRESSURE STEAM PIPING

This includes all steam piping whose internal steam pressure is under 50 lb. per sq. in., and also includes piping for steam vacuum service. This class of piping presents one of the most fertile fields for welding both in pipe and fittings made from pipe. For this class and all ordinary work none of the elaborate details used for high pressure steam service are required. First, because of less hazard; second, because the fluid pressure is less, and third, because the expansion in length is less. due to the lower steam temperature. If no superheat is present, 50 lb. pressure will give only 297.5 deg. Fahr. or a difference of 297.5-70.0—227.5 deg. Fahr. of hot pipe over cold pipe for the highest pressure in this class. Although the expansion is small in amount, it must, nevertheless, by no means be overlooked, but proper provision must be made to care for it.

In high pressure steam work bends are the most commonly employed for expansion allowance; in low pressure steam work, this is done by using expansion joints with the proper amount of travel, or by laying out the piping system to deviate from a straight path.

In low pressure steam piping, if the piping is fairly large in size, i.e. 10 in. in diameter or over, welding becomes a paying proposition, until in the larger sizes of about 18 in. or over welded pipe erected and ready for operation is so much cheaper as to make it the only method worth considering. At one time, only a few years back, the designer for real large work, i.e. over 18-in. diameter, was limited practically to C. I. pipe with integral flanges and C. I. fittings. The C. I. pipe usually comes in standard lengths of 12 ft., with shorter or spool pieces made to order. A 12-ft. length of 26-in. pipe in the lightest commercial size weighs 4,750 lb. When this pipe was used, very heavy supports and hangers were required for practically every length to prevent breakage and leaky gaskets. Breakage was also common in shipment and field handling, usually causing erection delay. At the time this paper is being prepared, we are engaged in changing a piping system containing this old style of C. I. pipe and in sizes 36-in. diameter and down to 30-in. with a few pieces of 14-in. steel pipe. In the old system there are 21 different pieces of pipe and fittings from one fixed point to two other points, making up about 60 ft. of pipe, but there is not one standard length of cast iron pipe; all are special and shorter. Only five fittings might be classified as standard. In the newer system, using welded plate or pipe, there are only 9 separate pieces from the same fixed point as above, and two other points further apart, giving 110 ft. of pipe. In the newer pipe system, although the pipe sizes are the same in places, and approximately the same in others, only one piece of the old material was used; scrapping the rest was justified in saving and handling costs, quickness of installation, saving in gaskets and erection labor for the additional joints, and last and most important, because of saving in hangers and supports.

Low pressure pipe and fittings made from pipe can now be purchased from fabricators specializing in this work, and of any thickness of material, depending on size and use, although ¼ in. is the most common thickness. The pipe in the larger sizes is made either from plates with both longitudinal butt welds and circumferential welds or else with lap hammer welded pipe with only circumferential welds. The lengths are usually as long as convenient for shipping. Fittings in the larger size can be procured either for standard A. S. M. E. dimensions or any practical dimensions. Special fittings to any dimensions, or pipe with outlets can be purchased and present no difficulties or cause for delay. Delivery on this class of work is surprisingly quick considering the amount of special construction called for at times. Hammer weld pipe is more expensive than longitudinal butt weld, and whether or not its use is justified depends upon the individual viewpoint.

All the piping above described can either be butt welded in the field, or flanges may be used, or a combination of both. The writer prefers the combination method because this permits welding in convenient points and bolting where it might be difficult to weld. If flanges are used they can be procured with the ends Van Stoned, as illustrated in Fig. 1b, for high pressure piping, except that the flanges are made lighter and without the long hub and of either cast steel or forged steel. Or they may be bought with loose flange, for riveting in field, and caulked; or flanges can be welded in field. Another type of flange used is that made by burning out a plate to a ring form and welding the ring to the pipe or a steel casting

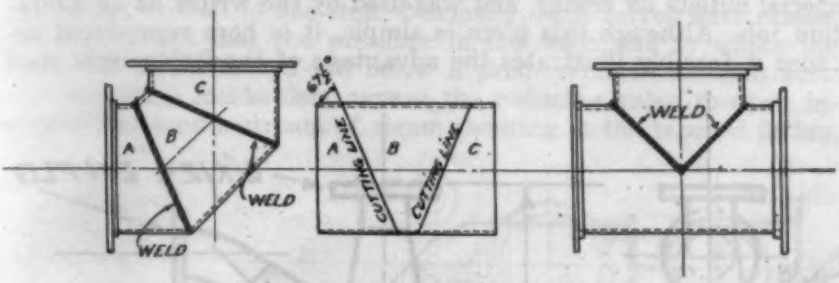


Fig. 8. Low pressure steam fittings

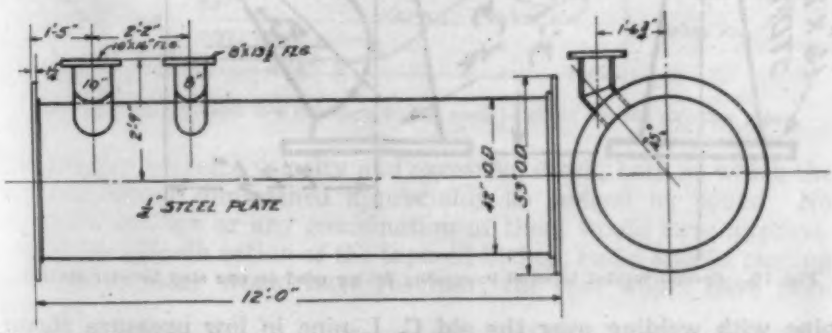


Fig. 9. ¼ in. steel pipe with welded cast steel flanges and welded outlets replaces cast iron pipe

might be procured and welded to the pipe. A good home-made flange, if rolling equipment is available, can be made by rolling an angle iron to ring form and then welding to the pipe. An expanded sleeve may also be used for low pressure pipe; this simplifies alignment in field before welding.

The flanges used for this work can either be drilled to the American standard for 125-lb. pressure, or to the lighter Riveted Pipe Manufacturers Standard. The latter drilling is generally satisfactory for all conditions except for bolting to a valve of fitting with the American Standard Drilling.

In making up fittings, the elbows can be obtained in either three pieces, four pieces or any number of pieces, but in all cases the fittings are developed to prevent all waste of pipe or plate. One

piece of pipe or plate is all that is required to make an elbow. The greater the number of pieces of pipe in a fitting, the greater the number of cuts made, the greater the number of welds, the greater the cost. Fig. 8 shows how an elbow can be made from three cuts in a piece of pipe; 45 deg. elbows can be made in a similar manner. The welds on a standard straight tee are also shown in Fig. 8. Reducing tees, straight or reducing crosses, side outlets or bases to suit any desire of the designer can be obtained. It is also a simple matter to weld steel lugs for support or suspension anywhere desired; this simplifies the hangers.

Fig. 9 depicts a piece of 42-in. diameter 12 ft. long pipe with two special outlets off center, and was used by the writer as an alteration job. Although this piece is simple, it is here reproduced because it forcibly illustrates the advantage of the lightweight steel

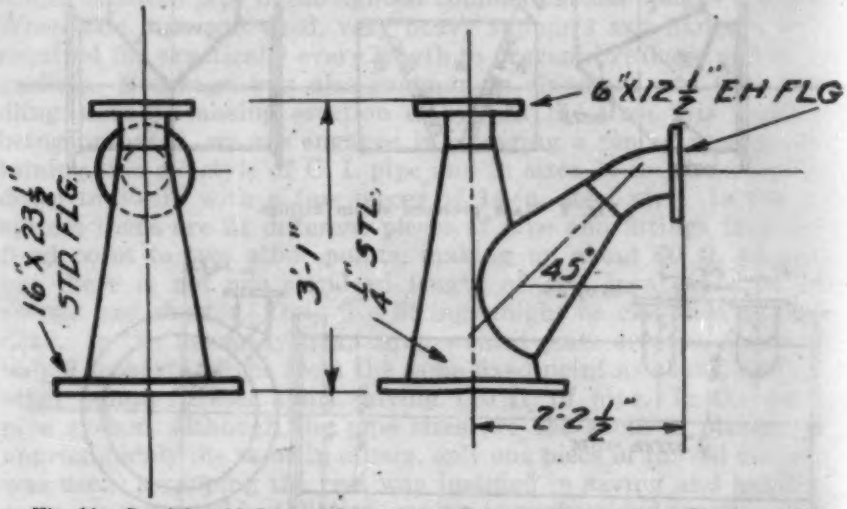


Fig. 10. Special welded tapered increasing fitting used on one step booster station

pipe with welding over the old C. I. pipe in low pressure steam work. This was an alteration job, where it was necessary to run the exhaust from two new reciprocating units into the exhaust main. The main was installed some years ago, when the use of C. I. was the prevailing practice. This alteration made in any way required a plant shutdown, and had to be done at a period of low load or no load. The time available was therefore very limited. All possible methods were studied out, including welding an outlet to steel studs tapped into the C. I. pipe, the method of cutting a hole and attaching a steel nozzle with patch bolts, etc. But these were all eliminated because of the element of chance involved pertaining to cracking the pipe and prolonging the shutdown period. The method finally decided upon was to purchase a pipe of 42 in. x 12 ft. pipe made with cast steel flanges at each end welded inside and outside, and the two outlets also welded. The material was on the ground ready before the shutdown period, and with a valve bolted

on to one outlet, and a blind flange on the other outlet. The cast iron pipe to be replaced was in a pipe trend and weighed 6200 lb. Fortunately a 20-ton crane was available overhead to remove the pipe. The new steel pipe was inserted without any trouble, the joints made and the line turned on. How much simpler would it have been had the original pipe been of steel?

Fig. 10 illustrates how easy special work can be made with welding. The tapered sections were necessary because of the nature of the service. At one small end of this fitting was attached a reducing valve used as a booster; at the end a globe valve was attached. Either valve expanded from 150 lb. per sq. in. to 4 lb. per sq. in., and all in one step. Normally, both valves were closed, but the instant that the pressure in the main and to which the large end was attached fell below a predetermined amount, suitable actuating mechanism caused the reducing valve to open instantly and send a stream of steam shooting at the tapered fitting,

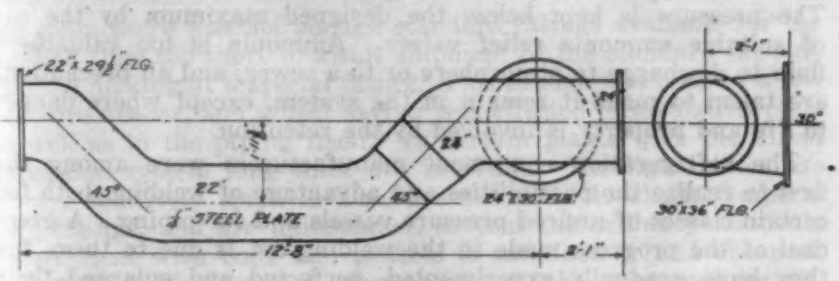


Fig. 11. Butt welded low pressure fitting used to offset around existing pipes

resulting in extreme velocity and excessive shock, both of which the tapered fitting diminished appreciably as judged by sound. No standard fittings or any combination of them would have approximated the smooth action of the tapered fitting; had a special casting been used, delay would have resulted; the cost would have been higher.

Fig. 11 illustrates a large fitting that could be approximated with standard cast iron fittings, but at greater cost.

In vacuum steam or process work, all welded work is especially desirable to prevent all air seapage, inwards to the system. Air keeps the pressure up in a vacuum system, involves power expense for removal, and if not removed, adversely affects the economy of the system. In this class of work it is preferable to use only such flange joints as facilitate the erection and taking apart of the system in the event of repairs. Welded flanges should be used in this connection because once made tight they always remain tight.

REFRIGERATION PIPING

Ammonia piping may be under two different pressures. All piping from the ammonia expansion valve to the suction shut-off valve of the compressor. is known as low pressure piping, and is

normally under a relatively low pressure, or under a vacuum. Certain factors in operation can sometimes place this side of the system under high pressure and should, accordingly, be designed from the strength viewpoint exactly the same as for the high pressure side. The piping on the low pressure side except the cooling coils is almost without exception always covered with cork or other appropriate insulation. This factor of insulation is highly important from the welding standpoint, as will be shown presently.

All piping from the ammonia compressor discharge back to the expansion valve (except piping to and from the intermediate cooler if the system is compound), is under condenser pressure, and is known as high pressure piping and is invariably uninsulated. The upper limit of this pressure is fixed solely by the temperature and quantity of cooling water available for the condensers, and the quantity of inert gas in the piping system. 300 lb. to 350 lb. per sq. in. is the pressure always designed for in the Northern States. The pressure is kept below the designed maximum by the use of suitable ammonia relief valves. Ammonia is too valuable a fluid to discharge to atmosphere or to a sewer, and all precautions are taken to make it remain in the system, except where danger to life and property is involved by the retention.

The refrigeration equipment manufacturers were among the first to realize the possibilities and advantage of welding, both for certain classes of unfired pressure vessels and for piping. A great deal of the progress made in the welding art is due to them, for they have gradually experimented, perfected and enlarged their welding equipment, methods and organization, until today certain of the refrigeration equipment makers are among the largest users of welding. The chief use of welding in ammonia piping is for welding nipples, pipe couplings and blank ends on headers, and pipe outlets, etc., on pressure vessels. Welding in headers eliminates flanges and gives great compactness. The outlets are usually made of pipe material standard or extra heavy and using either the pipe itself or couplings. The flanges on outlets when used are always of the tongue and grooves, or male and female type.

Ammonia pipe flanges are invariably screwed on using a thread compound such as litherage and glycerine, or the flanges are tinned and sweated on. Pipe with this type of flange when installed and left in service a number of years and then taken apart, should be tested for thread leaks before being reinstalled, or some of the work will have to be done over again. It is most economical and time-saving to burn off the ends of the pipe, and then to rethread or weld the ends of the pipe together. The writer is familiar with one installation where between 15 to 20 lengths of reclaimed 8 in. and 10 in. pipe were installed without any such test; the result was over 25 per cent leaks when tested under air.

In another installation with which the writer is acquainted, ⅜ in. ammonia bends for discharge lines to condensers were purchased. All three proved defective; the thread was cut eccentric

in one of the bends leaving a thin pipe wall in one side; in another the pipe was bent to the wrong dimensions, and in a third the thread was defective. Ordinarily this would have meant delay on a rush job, but the use of the cutting and welding torch saved the day. The ends were burned off and sleeve welds were used to reunite the pipe.

Fig. 12 is from a design by the writer used on an alteration

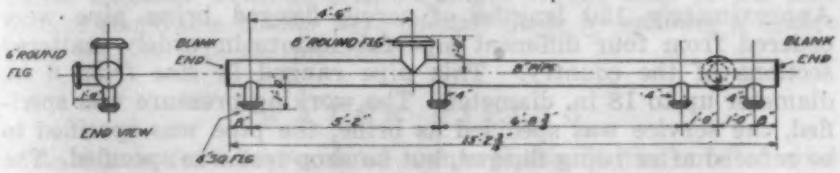


Fig. 12. Ammonia header used to save time and cost of insulation

job when there was not enough standard fittings available for the job and time too short to await shipment of the standard fittings, and the making of a special fitting. This header was used as a low pressure header, and a neat saving was effected in insulation costs as well as in the piping itself. In certain plants with the direct expansion system long lines are involved. The liquid lines are always relatively small in size, are subjected to slight temperature change, and are uninsulated, so that the ordinary ammonia flange joint with bolts and gaskets is satisfactory and cheapest, except for those installed where access to the joint may be difficult, in which event welding is justified. The low pressure return gas line is relatively large in size, is insulated and contracts in service. Plain butt welds in line joints in this service would be more satisfactory than the flanges.

BRINE PIPING

Brine is the usual refrigeration medium when the indirect expansion system is employed. The ammonia is kept inside the refrigeration plant, and the cooling of brine takes place in the brine cooler. The brine is pumped to service points from the coolers, and at the service points the brine is warmed a few degrees, and is then returned to the cooler for further cooling. A brine system hence involves two lines; the supply and return usually of like or, approximately like sizes. Refrigerating brine lines being under low temperature all require insulation. The gaskets on brine systems, if of the proper type and properly installed, are rarely a source of trouble (the writer knows some that have been in service over 15 years without trouble of any kind). In spite of this, however, welding has a rich field in brine piping. All pipe flanges on brine carrying lines must be insulated. First, because of the economy obtained; second, because were the flanges left bare, they would frost up and be a starting point for

rotting a greater proportion of the adjacent covering. Pipe flange covering, especially in larger sizes is expensive. If the cost of the fitting necessary to obtain an outlet, the bolts, the gaskets, the cost of installation and additional insulation charges are considered a very handsome saving can be effected by the use of a brine header.

In the design of a recent extensive brine system a good example of the advantage of line welding over screw flanges occurred. Approximately 150 lengths of screw flanged brine pipe were ordered from four different pipe fabricators in widely scattered sections of the country. This pipe ranged in size from 6 in. diameter up to 18 in. diameter. The working pressure was specified, the service was specified as brine, the pipe was specified to be refaced after being flanged, but no shop test was specified. The material was received in field and erected, and then tested under water pressure. This test revealed approximately 25 per cent leaks all at the threads, and pipe from all of the four fabricators was represented among the defective samples. Were the pipe for water service these defects would have been comparatively unimportant, because in a short time they would have cemented or rusted shut, but calcium chloride brine keeps the thread clean, so something else had to be done. After attempts at repair it was found that the work could only be repaired by burning off the defective threads and rethreading the shortened lengths in some cases, and in others, rewelding with the sleeve reinforced weld.

On another section of this same job 1300 ft., approximately of 10 in., 12 in., 14 in., and 16 in. brine line was installed without a single flange or fitting except at the extreme ends of the line; it was an all welded job with the sleeve reinforced weld. The joints were tested under pressure, a very few proved porous and were remedied by reworking the metal around the defect with the torch. The whole piping system was then insulated and completely covered in underground with no provisions for access. No unaccounted for brine disappeared from the system, so evidently the lines proved tight.

In both brine system and low pressure refrigeration system the ordinary expansion is negative, i.e. a contraction and comparatively small in value, but, nevertheless, provision must be made to care for this.

AIR PIPING

Air piping can be classified as either high or low pressure. High pressure air is discharged from an air compressor; low pressure air is discharged from a fan. High pressure lines as a rule do not attain large size, and screwed fittings are satisfactory for most work. In special cases, such as long lines, special fittings, etc., any of the welds described for high and low pressure, steam may be used.

Low pressure air is handled usually in large volume and for

ordinary work galvanized iron and soldered joints are satisfactory. However, for pressure slightly above that common in ventilating work, say 4 in. of water pressure or over, and where thickness of metal must be comparatively heavy to provide for corrosion, welded ducts can be used to advantage. The writer employed all welded air ducts to good advantage in remodeling the air supply to a stoker system recently where material used was ⅛ in. plate made into 30 in. diameter and scrap pieces of standard pipe from 16 in. diameter down to 8 in. Flanges on the ends of the pipe to take removable blanks were cheaply made by welding a square plate with hole to the pipes.

WATER PIPING

As a rule for above-ground water piping in the smaller sizes screw fittings are satisfactory, and for cold water work in the large sizes galvanized spiral riveted pipe is satisfactory for all ordinary work. The cost of such material ready for erection is usually so low that welding does not, as a rule, pay. But, for large fittings, special fittings, outlets, etc., welding is very economical. A 5 in. return water line paralleling the 4815 foot 12 in. line described earlier in the paper, was installed very economically, all with screwed couplings and a few cast iron flanges; but welding was used to very good advantage for all outlets, drips, etc., which had to be small and compact to minimize danger of freezing in dead pockets. Every 20 feet a small piece of channel was welded to the pipe to act as a support. For hot water lines placed underground with no provision for access, plain butt welding is very satisfactory.

GENERAL FLUIDS

In certain classes of fluids handled in very large volumes, welded piping can be used to very good advantage. The type of welds to use is the same as any described in the previous classes, depending on which class these fluids approximate.

STRESSES

In line welds the plain V-type butt welding is subjected to a bursting stress given by Barlow's formula:

$$S = \frac{PD}{2t}$$

Where S = stress in pounds per square inch; P = pressure in pounds per square inch; D = outside pipe diameter in inches and T = thickness of pipe wall in inches, or thickness of weld metal.

In addition to this a pipe may be subjected if heated or cooled to expansion stresses which may be greater in amount than the stress due to pressure. The paper by Sabin and Crocker already referred to indicates how to compute the amount of these stresses.

For 100 per cent efficiency, proper and complete fusion must be obtained between the pipe and weld metal, and the tensile strength of the weld metal deposited must be equal to that of the pipe. The above formula indicates that if the weld does not penetrate the full depth of the pipe the thickness will be smaller and hence S greater; if the thickness of the weld is increased the stress will be less.

In the V-butt weld reinforced with sleeves, the butt and sleeve are figured separately and not as complements of each other. Either the V-weld or the sleeve should be strong enough to take all the stresses in the piping. The sleeve welds are subjected to stresses due to bursting acting in direction of pipe axis and tension and shearing stresses due to expansion strains.

If a welder can make, for example, 999 welds out of 1000 which will remain tight in service after proper tests, with the plain V-weld, there is one chance in one thousand of the weld being defective, not necessarily, of course, leading to complete failure. If now, this same welder makes up a sleeve reinforced joint with ring sleeve, and the welds were designed as above indicated, there are two chances in a thousand of a defective weld in the sleeve. Since the butt and sleeve are computed each for taking all the stresses, the only possible way to have a noticeable defect, i.e., one that will lead to leaks or to failure, is to have the butt defect and the sleeve defect synchronized.

The chances of synchronism is one chance in 1000 x 500, or one in a half million. If the defect leading to complete failure in a welder's work occurs even as frequently as one in 10,000 welds, the chances for failure in a sleeve reinforced joint is one in 50,000,000. If the sleeve used is split longitudinally there are two more weld joints and the probability of defects would be one in a quarter million; probability of failure would be one in twenty-five million. For the comparison to hold strictly, it would be necessary to test the butt joint first before welding on the sleeve, and then to test out the completed joint. But usually the completed joint only is tested and only synchronizing defects are evident.

TESTS

In designing a piping system a factor of safety of at least six is used, and this factor should also be used in welded work. At the mill commercial pipe is subjected to hydraulic tests to locate imperfections, and to determine security of the manufactured weld. These test pressures are high and should not be taken as safe working pressures. The following table gives the test pressure used by the National Tube Company, see Bulletin No. 10. The ultimate bursting pressure given in last column is computed from Barlow's formula using 50,000 pounds per square inch tensile strength. The pipe is all full-weight, steel pipe under 12 in. and ⅜ thick 14 in. and over.

Size of Pipe	Test Pressure in Pounds Per Sq. In.	Bursting Pressure in Pounds Per Sq. In.
6	1,000	4,230
8	1,000	3,730
10	900	3,400
12	800	2,940
14	750	2,680
16	700	2,340
18	600	2,080

If any autogenous weld is to be as strong as the pipe, it should be subjected to a like test pressure, and tests on pipe to destruction should come up to those given in the table which are based on values of tensile strength obtained from Barlow's formula and actual pressures. But in practice this is never done because it is not deemed necessary. For high pressure steam work the test usually applied is hydraulic pressure two to three times the maximum working expected pressure, pounding the joints with a hammer while under test pressure. If any defects exist in the welds they are indicated by small leaks or sweating. Some engineers require the cutting out and remaking of all joints that sweat under pressure and rewelding; others merely require reworking the metal in the vicinity of the defect with the torch. The writer deems the latter method satisfactory, for experience indicates that once a welded line is made tight under water pressure and impact it will never leak steam. After the above test it is usual to make a temperature test by feeding steam very gradually into the line till the full working pressure is built up. This test is made before covering the line.

For very low pressure steam lines a satisfactory test is made with 50 lb. hydraulic pressure, but without impact, if supports permit the weight of the water. Air at this pressure may be used but is generally more laborious. Sometimes for very low pressure the test is omitted entirely, but never in vacuum work. Steam is turned on gradually; if no leaks develop when up to pressure, the line is ready for operation.

Ammonia lines in field are tested to 300 lb. or 250 lb. air and soap bubbles, and in shop are tested to this air pressure under water. In the high pressure side of the system the impact test should always be used in conjunction with the air test.

Brine piping is tested with hydraulic pressure equal to twice the working pressure and impact. Air piping should be tested with air and bubbles if on a compressor discharge. No test is required for air piping used in fan work. Water piping is tested the same as brine piping. General fluid piping is tested as conditions warrant.

MATERIALS AND WORKMANSHIP

In all installations with which the writer is personally acquainted, the material used for pressure up to 350 lb. is standard full-weight pipe, except when very small size nipples or outlets are used, when extra heavy is sometimes necessary for increased thick-

ness required to make a good weld. No special pipe was ever used, the pipe was commercial pipe taken from ordinary pipe stock bought to ordinary specifications from a reputable mill. No preference is ever made as to open hearth or Bessemer steel, although some welders prefer the open hearth. In all welded joints made both electric and oxy-acetylene, the author has come in contact with in piping and unfired pressure vessels, not one has ever shown a defect after proper tests were made.

The maintenance and construction organization of a large manufacturing concern has two sources for welded pipe: it can fabricate its own piping or it can purchase it. Usually it will be found more economical to purchase when a large quantity of work is to be installed and sufficient time is available. Fabricating shops are all equipped for economical manufacture of welded piping, have better facilities for tests, better supervision, and greater experience. The general welder in the maintenance shop can, however, turn out work that compares favorably with that of specialists. To obtain the best and most satisfactory work from a welder or any artisan, it is absolutely essential that he should be conversant of what is to be expected of his work. To illustrate this the following table is given. It was desired to ascertain which was the most desirable and reliable method of attaching certain pieces of steel, notably threaded turn buckle ends. There are three methods of doing this. One is to use a full rod of the proper length and threading, but this requires a left-hand thread to be cut as well

TESTS ON RODS

Type and Size	Ultimate Load Per Sq. Inch	Point of Break
Plain ¾"	60,000	Full rod
Plain ¾"	75,500	Full rod
Plain ¾"	75,900	Full rod
Plain ¾"	77,800	Full rod
Plain 1"	49,000	Full rod
Plain 1"	62,500	Full rod
Plain 1"	61,800	Full rod
Plain 1"	62,100	Full rod
Forged ¾"	50,000	Weld
Forged ¾"	61,200	Weld
Forged ¾"	37,800	Weld
Forged 1"	45,000	Weld
Forged 1"	62,000	Weld
Forged 1"	50,400	Full rod

Type and Size	Ultimate Load Per Sq. Inch	Point of Break
Forged 1"	50,500	Full rod
Oxy-Acetylene ¾"	45,500	Weld
Oxy-Acetylene ¾"	27,300	Weld
Oxy-Acetylene ¾"	38,800	Weld
Oxy-Acetylene ¾"	50,300	Weld
Oxy-Acetylene ¾"	50,300	Weld
Oxy-Acetylene ¾"	60,500	Weld

Average for plain rod 65,560 = 100 per cent.
Average for hammer weld 50,980 = 78 per cent.
Average for Oxy-Acetylene 45,500 = 69 per cent.

as a right-hand one. Another method is to forge weld the threaded pieces, that come with the turn buckle, to a plain rod. The third method is to forge weld the pieces. In making the test, pieces were cut off lengths of 1¾ in. rods, from stock bought to the same specification, and in this case of high tensile strength, were mixed. Some were given to the blacksmith, others to the welder, and both were told to weld the pieces together, with no mention of intended use for testing or otherwise. Samples of the full rod were also obtained.

For the plain rod the lowest value is 74 per cent of the average; for the hammer weld the lowest value is 58 per cent of the average of the plain rod; for the oxy-acetylene the lowest value is 42 per cent of the average for the plain rod. The lowest value of each type compared with its own average is 74 per cent, 74 per cent and 60 per cent respectively. It should be noted that no restriction was placed on the thickness of the metal to be used at the point of joining.

When the results were shown to the shop, prompt protest was made that the results were not a fair sample of the work of the shop, because the samples were thought to be for use in some relatively unimportant work and were made accordingly. The shop then made their own samples with the request that they be tested. The steel selected was all from ¾ in. round rod and similar to pipe steel in composition. Unfortunately, but one sample of welding was submitted, but apparently the shop was willing to stake its reputation on the one sample.

RESULTS OF TEST ON ¾-INCH RODS FROM OUT OF SAME PIECE OF STOCK

Type	Ultimate Load Per Sq. Inch	Point of Break
Plain	49,500	
Plain	49,100	
Plain	48,800	
Electric weld	47,700	End of weld
Forge weld	49,700	Outside of weld
Forge weld	49,700	Outside of weld
Forge weld	50,000	In weld

Note the uniformity of the results.

Piping fabricated welded in the shop is sometimes annealed by heating over a flame, or by applying the annealing temperature from the welding torch. In the field it may be annealed by working the flame around, or may not be annealed at all, only attempts may be made to prevent strains in welding.

In purchasing material it is best to leave this feature entirely up to the fabricator; he knows from experience what strains are set up, if any, and the methods of releasing. No fabricator of any prominence will risk his reputation on any but the best of welded work.

In purchasing fabricated welded piping the kind of weld; i.e., whether gas or electric, should be left up to the fabricator. Doing this does not restrict bids as some fabricators are equipped for

the one process, other welders are equipped for the other processes. In purchased piping the gas weld seems the most common for high pressure work, while in low pressure work the electric process seems to lend itself better to production. In the maintenance shop, the gas apparatus seems to be the favorite because of its portability, but usually it also pays to have the electric weld equipment for certain classes of work.

In this paper no mention will be made of proper fusion rods to use or actual welding procedure. This will be left for the practical welders. It is merely the attempt of the paper to indicate correct engineering principles involved in welded piping design, and to show the boundless possibilities of welding in piping when used under proper conditions.

CONCLUSIONS

The welded pipe joint is a satisfactory joint, easy to make, comparatively cheap for large size pipe or for high pressure pipe, is a time saver, gives the designer perfect freedom in piping layout, and once made tight, stays tight. It saves in insulation cost, and it reduces the coal bill even if unappreciably in amount. Its use makes possible certain economies in the industrial power plant pertaining to steam distribution, in permitting concentration of power and heat production. Low pressure steam distribution can be made in very cheap steel mains of large size, which has the advantage of being able to be added to at very low cost. It is the writer's opinion, based on experience, that welded piping installed under proper supervision is fully as reliable as any of the other ordinary joints. True, a welded joint has resulted in failure now and then, but so have the other type of joints. C. I. fittings frequently fail, riveted vessels fail often, and gasket blow outs are a common occurrence.

Welded joints have been scrutinized for defects and each defect magnified. But in a certain measure this close observance is beneficial, for it has taught caution in a comparatively new art. The fact that welded piping is now in such extensive use, and its use increasing day by day, indicates that criticism has not been in vain.

This precaution must not be so stringent as to throttle welding, but must be rigid enough to secure against failure. The best precaution possible is to use only welders and welded material of known reliability, i.e., deal only with fabricators and welders who value their reputation.

The piping designer should cooperate with the maker of welded material; he should properly allow for all stresses, expansion, pressure or otherwise. And, if possible, he should keep welds, unless properly reinforced, away from points of maximum stress. Welding is a most important tool to the piping designer, and he should understand both its possibilities and limitations.

The Design and Manufacture of a Horizontal Cylindrical Pressure Tank*

L. H. BURKHART†

Size of tank is 48 in. diameter x 15 ft. long on cylindrical shell. Heads dished outwardly.

The tank is to be used as an air or steam receiver under 250 lb. pressure.

A manhole and the required openings, fitted with nozzles or screwed flanges, are to be a part of the structure.

The tank is to be made by fusion welding throughout and is to be according to the Unfired Pressure Vessels Code, using the unit stress of 8000 lb. for double V welded joints.

Standard flange steel will be used.

The thickness of the shell is found by the following formula:

$$T = \frac{PR}{S}$$

When T = thickness of shell,
P = Pressure,
R = Radius of shell,
S = unit working stress = 8000 lb.

substituting we have: $T = \frac{250 \times 24}{8000} = .75$ in. $= \frac{3}{4}$ in.

The thickness of the heads, when dished outwardly, is found by the following formula:

$$T = \frac{5.5\ PR}{2S} \text{ plus } \frac{1}{8} = \frac{5.5 \times 250 \times 48}{2 \times 55{,}000} \text{ plus } \frac{1}{8} = \frac{3}{4} \text{ in.}$$

We will place a 11-in. x 15-in. manhole in one head. Therefore, according to the Code the head containing the manhole will be $\frac{1}{8}$ in. thicker than the head without the manhole.

The size of the plate required for the shell, if made of one plate, is 180½ in. x 154 in. x ¾ in., weighing 5850 lb. This size of plate, according to the Mill schedule of width extras, will cost $1 more per 100 lb. than if the shell is made of two plates with a double V welded girth seam at the center. The cost of this extra girth seam is less than the extra, viz., $58.50 on the wide plate.

As an alternative construction the shell can be made of one course of two plates with two longitudinal seams with approximately the same amount of welding and without any extra for wide plates. Such a construction requires the use of a plate bending roll that will roll plates 15 ft. wide. Not all shops are so equipped so I am showing a construction that will suit most shops.

*To be presented at annual meeting, A. W. S., April, 1926.
†Chief engineer, Struthers-Wells Co.

The heads will be dished to a radius of 48 in. inside and flanged with a flange of the depth shown on standard mill card for dished and flanged heads. For a 7/8-in. head this flange is 5½ in. deep, which includes the radius of the flange.

The shell and heads will be prepared for welding as follows: The two shell plates will be 90½ in. x 154 in. x ¾ in. in the rough. They will be planed on all four edges, half way through, to an angle of 30 deg., so when they are assembled the joints will show an open V of 60 deg. The heads, which in the flat are 58 in. diameter, are dished and flanged either by the spinning process or in

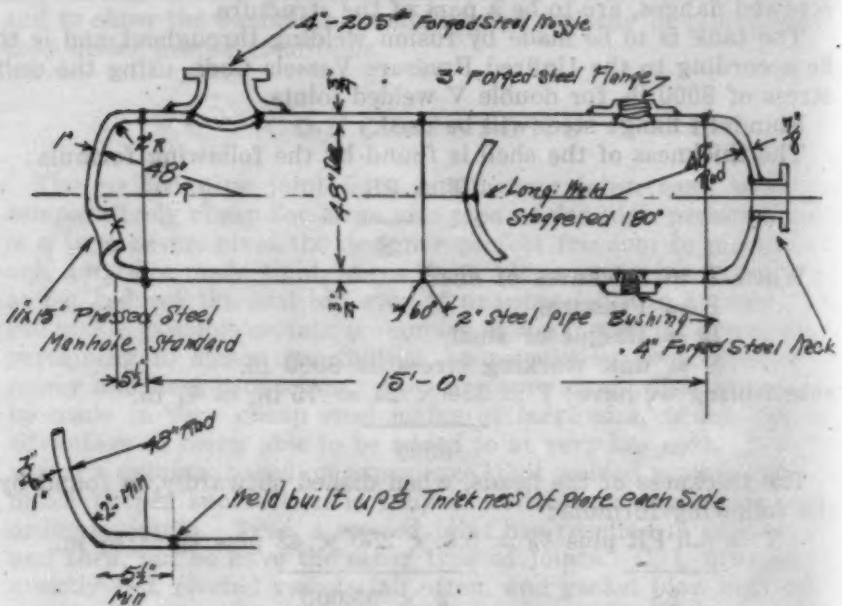

4"-205# Forged Steel Nozzle
3" Forged Steel Flange
48" R
Long. Welds Staggered 180°
11"x15" Pressed Steel Manhole Standard
2" Steel pipe Bushing
4" Forged Steel Neck
15'-0"
Weld built up ⅛ Thickness of plate each side

Fig. 1. Electric welded air or steam receiver 250 lb. working pressure

dies on a press. The heads are to have the flanges turned to a bevel of 30 deg. and the flange from the inside faced to the thickness of the shell plate, this to facilitate the making of a weld on the inside. The shell plates have their edges bent to 24 in. radius and are then completely rolled to a true cylinder and clamped in this position.

The long seam of each half of the shell is now welded by placing one string of welding on the outside and another string on the inside, the welds to be built up at the center about one-eighth the thickness of the plate and sloped gradually to the parent metal without a depression. Such a weld will have a greater tensile strength than the plate, it is a 100 per cent joint.

The shell sections and heads are now assembled and tack welded to a true alignment. One string of welding is placed in the V on the outside and one on the inside and both are built up as explained

for the long seam. The assembly of the parts and the make up of the welds are shown in the accompanying drawing.

After the tank has been welded and all openings attached as shown, a test of 500 lb. hydrostatic pressure is applied. The tank may be pounded with a heavy wooden mall until one is exhausted if you wish. This pounding will have no effect on the welds and could just as well be omitted. Welds made as described will never open under a hammer test. If a hammer test is insisted upon it should be done by using a heavy wooden mall and not a steel hammer, which dents the plate wherever it strikes.

The tank, as described above, contemplates the use of metallic arc welding. By the use of such a process fewer stresses are set up and left in the welded seams; less warping and distortion of the parts occurs and the strength of the welds is greater.

If the above tank were to be made riveted, using quadruple butt strapped joints with an efficiency of 93 per cent, the shell plate could be $\frac{5}{8}$ in. thick with a factor of safety of 5, which is all that is required. The edges that are usually caulked can be caulk welded, thus making the riveted tank as tight as the welded one. The welded tank will have joints of 100 per cent and we know the riveted tank will have joints of but 93 per cent, a lower efficiency of joints, yet the plate of the shell for the riveted tank is thinner than the shell for the welded tank. This is because the unit stress of 8000 lb. is too low. To place welded construction on an equal basis with riveted construction, the unit stress of the welded joint should be taken at 9000 lb., and this unit stress is not too high for the double V welded seams in plate of not less than 55,000 lb. tensile strength, when you consider that the weld has at least 25 per cent more section in it than the plate. If 8000 lb. is to be considered the unit stress in the joint, the strength of the joint should then be computed on the basis of the built up weld, which is from 10 per cent to 25 per cent more than the plates.

Gas Welded Longitudinal Seams for Stringent Requirements*

A. C. VICK†

The welding industry at the present time is enjoying a very rapid progressive march with which few people are familiar. Great progress is being made in all kinds and types of flash butt welding resistance welding, cutting, etc. Progress at the present time is so rapid that it is somewhat difficult to keep even well posted on the industry. In the past welding has been given a great deal of criticism and has been looked at and followed with a great deal of skepticism. However, the welding industry at the present time is in the happy position of having a great many manufacturers, who are thoroughly sold on its possibilities as a result of having followed it very closely and given it time, study and money without restraint. To these manufacturers can be given a great deal of credit for the progress of the industry.

The Detroit Range Boiler & Steel Barrel Company of Detroit, Mich., found early in the history of their business that welding of many types and forms would be of unlimited value to them, and as a result a great deal of experimenting has been carried on for a good many years. Welding of various types and forms is being used in different ways, and the management has kindly consented to permit the history of one of the welding jobs that has been extremely difficult to whip and control to be given. However, at the present time they are in the happy position of being able to say that they have won a great victory, and in the writer's opinion, those who are familiar with welding will heartily agree when once they are made familiar with the facts concerning the job.

At this point we find it necessary to go somewhat into details, in that the particular welding job we wish to describe is involved in the manufacture of what is known as "Bilge" barrels. We shall avoid as much as possible operations that have no bearing on the welding in order that we might pursue our subject closely, namely, "welding." However, we find it necessary to get away from welding a trifle at times.

The "Bilge" barrel gets its name from its shape, which is bilged or bulged in the center of its strength. The main part of the barrel is referred to as the shell, and this shell is made from a flat sheet of steel which is carefully resquared with a squaring shears on the two edges which butt together when the sheet is rolled and which forms the joint that is to be welded. The gage of the shell varies somewhat according to conditions and runs from 12 to 14 United States Standard Gage inclusive. After the shell has been welded it is then placed on what is known as an expander

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†Plant engineer, Detroit Range Boiler & Steel Barrel Co.

which, in itself, is nothing more than an expanding arbor, which, as it expands forces the shell to expand and take the exact shape of the mandrel itself. This operation is known as "bilging."

In "bilging" a 55-gal. bilge barrel shell, the diameter is increased from 21 in. to 24½ in. at the bilge, the end still remaining 21 in., the diameters at intermediate points being governed by the height of the segment at that particular point.

This will give you somewhat of an idea of the stringent demands put upon the welding.

The expansion of the 3½ in. at the bilge effects an elongation of 11 in., which is distributed over 66⅜ in., the circumference of the original cylinder; this is an elongation of 0.166 per inch of circumference.

The elongation effects a reduction in thickness of approximately 0.007 of an inch which, in the case of a 13 gage shell, is a reduction in area of 7½ per cent.

The writer feels certain that those familiar with welding will appreciate the difficulties encountered when the manufacture of the shell by this method was undertaken, and we shall endeavor to go back some few years and give a general idea of the history of the method.

As near as can be ascertained by records, this was undertaken in about the year 1914. As you all know the analysis of the steel has a great deal to do with the strength of the weld, and also its welding possibilities and characterstics. The tremendous test to which this weld is subjected in the bilging operation made it a very difficult proposition. However, the steel companies, after having carefully gone over the operations were so confident that they could furnish the proper analysis steel, that they guaranteed to allow the company full credit for all shells which broke in this operation. Consequently, orders for limited quantities of steel were placed, which in turn were filled by the mills and shipped to the plant for trial.

When everything was in readiness a few sheets were welded and tried, a single weld being used on the outside and but very little wire added. When the attempt was made to bilge these shells the breakage was found to be 100 per cent and it was soon very evident that the difficulties had been very greatly under estimated. In every case the welds themselves proved to be the weak point. When the second attempt was made a great deal of wire was added, but the weld was made on the outside only as before. The results of these welds were the same as previously, namely, 100 per cent breakage. A third attempt was made with the shells welded on the inside and the outside and with the use of plenty of wire, this attempt showed the most satisfactory results of all. Four out of ten shells were finally successfully bilged. Since steel companies had agreed to allow full credit for all breakers, manufacturing continued on that basis, namely, 60 per cent breakers

or six out of every ten. This, of course, soon began to be a very heavy burden on the steel companies, who in turn began making frantic efforts to supply a steel of the proper analysis to better withstand this operation and with some degree of success. The percentage was finally raised to five out of ten due to their efforts.

During this time no welding jigs were used at all and the process of welding consisted of tacking the shell at several points and then completing the weld, the shell itself resting in a cradle which was made of angle iron or pipe.

By careful and diligent study, approximately three years later, a welding jig was devised that enabled the welding to be done a great deal faster, and also enabled the welder to produce a somewhat better weld. An increase of the percentage of approvals of 10 per cent was a result of this, making 60 per cent that met all requirements. Intensive research work began about this time and continued for a period of approximately three to four years, during which time, through the combined efforts of the company and the steel company, the percentage was raised to between 85 and 90 per cent. However, during this time the steel companies had found the burden too great and refused to allow us credit on the breakers. This, of course, increased the already strenuous efforts of the Detroit Range Boiler & Steel Barrel Company on the welding. A quality of welding was finally attained that very rarely broke in the weld itself. In fact, only 5 per cent of the entire number of breakers broke in the weld itself, the balance being what is known as "zone" breakers.

The weld zone is considered to be the metal directly adjoining the weld, lying inside of lines paralleling it at a distance of 4 in. on either side—hence the welding zone is an area of 8 in. wide running the full length of the sheet with the weld running through the middle.

It is to be remembered that in the entire foregoing description the seam was welded both on the inside and outside of the shell. The outside weld being comparatively easy to make. However, the inside weld was entirely a different proposition. A good size tip was required which, of course, dissipated considerable heat, the length of the shell being approximately 33 in. A great deal of the heat was trapped inside of the shell and all of it was forced to exit at either one end or the other. To better facilitate welding, the shell was usually placed at a slight angle with the end at which the operator was working slightly higher than the opposite end. This, of course, created a condition in which the welder himself was forced to face the heat, which naturally flowed up to the high end of the shell. On 12 gage shells it was quite common for an operator to blister his face to no small extent. However, this condition was finally bettered a great deal by the use of small fans which forced the hot air out of the opposite end of the shell and permitted the welder to work a great deal more comfortably.

About 1921 the entire barrel business was moved to Toledo, Ohio, reinstalled and the work carried on. Efforts to improve the welding were never relinquished for a moment, and finally in the latter part of 1923 the welding had been improved through better jigs, better steel, better welding equipment and better operators to a point where it was finally possible to get entirely away from the double weld. When once the proper conditions were secured the elimination of the double weld was not such a difficult thing as might be thought. One of the objections to the double weld was the second heat of the steel that took place in the immediate vicinity of the weld. Conclusive tests proved that far better results could be obtained, if it were necessary to go over the seam *but once*, and the writer believes you will all agree that on hot roll stock the more often you heat the weld the lower the tensile strength of the steel adjoining the weld. It has been proven conclusively that to stop welding in the middle of the seam and allow the weld to cool before restarting, the weld produces a weak spot adjoining the weld at this point. Therefore, it is highly advisable when once a weld is started to make the entire weld without stopping.

At the present time under good conditions with steel of the proper analysis and annealing the "breakers" do not exceed 4 per cent. However, under poor conditions, that is, with steel of wrong analysis and poor welding qualities the percentage runs much higher and the fractures are not alone confined to the weld or welding zone, but may occur at any point.

The condition has been experienced where the material seems to be ideal for welding, but in bilging fractures occur in the welding zone, this is due to improper annealing and the effect of the welding on the steel adjoining the weld is to render it more "stretchable" than the rest of the sheet. When this occurs the steel in the welding zone is stretched to the breaking point before any appreciable stretching has taken place anywhere else on the circumference.

As before mentioned with good material the percentage of breakers is small, test welds made on 13 gage stock were cut in 1½-in. wide strips at right angle to the weld and were tested in a testing machine and broke at 1800 lb. at a point ½ in. from the weld. Proving that with good steel the welds could be made stronger than the original material.

Another important requirement is that the barrel be airtight after assembly, as the nature of the commodities sometimes shipped in these containers is such that the lives of men handling them would be endangered in case of any leakage.

The Interstate Commerce Commission Specifications No. 5 under which this type of container is manufactured calls for the following tests:

Each barrel must be tested under water or with all seams cov-

ered with soap suds, by interior air pressure of not less than 15 lb. per square inch and must stand this test without leakage.

Each barrel produced under this specification is tested in compliance with the above.

At intervals of three months barrels taken from the regular line of production are given the following tests in accordance with Specification No. 5.

A 40-lb. per square inch hydrostatic test sustained for not less than 5 minutes.

Any distortion of the heads due to this test must be such that they can be restored approximately to their original position (by hammering with a wooden maul or similar means), without leakage when subjected to a 15-lb. air test.

When filled with water to 98 per cent of its capacity this type of barrel must also be capable of standing without leakage a test by dropping it diagonally on its chime from a height of 4 ft. upon a solid concrete foundation.

These tests are for the purpose of subjecting the container to treatment similar to what it may receive under actual shipping conditions and when it is considered that barrels of this type have been in continual service for a period of thirteen years, one can appreciate the high standard of welding and manufacture under which they are constructed.

The above is a fairly accurate history of the difficulties encountered and overcome on this particular job. The writer trusts that it has been of interest and will be of some service to the reader in his particular line of work.

The Design of Welded Joints*

S. W. MILLER

In any industrial process, success is only obtained by following a definite procedure. In many cases, this is done unconsciously, rather than consciously, because experience has shown that certain things must be done if success is desired. Welding processes are not in any way different from others, and if it is expected that success should be attained, a definite procedure must be established as in other cases. It is convenient to apply the term "Procedure Control" to cover the various steps and items that are involved in successful work, and it has been found by experience that when the Procedure Control has been definitely established on a sound basis, success is inevitable. The various steps in this control may be considered to be the following:

1. *Workmanship*: Workmanship includes everything pertaining to quality of the welding and the determination of the ability of

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the welders. In important cases, tests of the welder's ability should be made by breaking test pieces either in a testing machine or by bending.

2. *Materials*: Materials include both the metal in which the weld is made, and the welding rod used. These tests would be such as to determine whether the materials are of suitable quality, and whether they meet the specifications under which they may have been procured.

3. *Design*: The design of a welded joint is of great importance, not only for strength but for ease and cheapness of manufacture, and the designer must often depart from the usual methods of joining, if he expects to get the best results from welding.

4. *Preparation*: This covers all such matters as jigs, fixtures, and other work preparatory to doing the actual welding.

5. *Welding*: This includes everything in connection with the actual welding operation, such as, the methods by which the parts are tacked and welded, allowances for shrinkage, the order in which different parts of the work shall be done, and the supervision of the welders.

6. *Testing*: In this are included any usual or unusual methods of test that may be devised to meet the requirements of welded structures. Sometimes special tests are necessary, and these should be worked out with care and good judgment, so that their application will prove the integrity of the work.

Each one of these, like links in a chain, must be of the proper strength, that is, satisfactory in all respects if the result is to be equally satisfactory. At the present time, design, which is just as important in welded structures as in any other, will be considered, and as one of the most important general divisions of welding is that of steel plate, it will probably be well to confine our attention to that branch of the subject.

It is easily seen that all of the above mentioned links in the chain are more or less interdependent, and before we can design intelligently, we must know something about the materials we are going to use. It will, therefore, be necessary to say a few words about steel plate.

There are four commercial qualities of this material—fire-box, flange, ship, and tank, and all of them are easily available in the market. All of them, also, except tank plate, are made under different specifications such as those of the American Society for Testing Materials. Tank plate, so called, has no definite specification, and in it may be found materials varying widely in chemical composition and physicial properties, much of it being the result of some difficulty in making a heat which has caused the heat to deviate to some extent from what was expected. For instance, the quality may have been poor, the chemical composition may not have been that desired—these difficulties being summed up in the general term an "off heat," so that while it may not be possible to use the heat for the purpose desired, the material is still good

enough to use in many cases, and it is, therefore, rolled into tank steel and sold as such.

It will be enough to say here, in order to avoid going too deeply into the question of materials, that tank steel is not good for important welded structures as its welding qualities are frequently undesirable and as the welds made in it will probably be inferior. Of course, for many purposes, it is good enough, but the designer should use discretion in employing material which is not up to the highest standard. It may also be said that as far as the physical properties are concerned, the material can be selected from any one of the four grades that will meet these requirements for each one—that is, tensile strength and other properties of tank steel can be the same as for fire-box steel. This is also true of the chemical composition.

There is, however, a difference between the grades that results from what occurs during the making of the heat. That is, the rather intangible "quality" of the material similar to that which we meet in every-day life in our ordinary wearing apparel, food, and other similar articles. No reputable boiler shop would use tank steel for the construction of the shell of a boiler, but would require the quality that is present in flange or fire-box steel.

For welding, it is important that high quality material be used for the best results, and, therefore, fire-box steel, which is the best grade, is most suitable for important work so that the designer in such case should use this quality of steel.

Such material, according to standard specifications, may have a tensile strength of from 55,000 to 65,000 lb. per sq. in. and a minimum yield point of one-half the tensile strength.

It is well known that the lower the carbon content of a piece of steel, the more readily it stands heating and cold work without injury. This is particularly true of heating, and as fusion welding involves a considerable amount of heating, we would use preferably a low carbon material. My personal belief is that material for welding should at the present time contain not over 15 per cent carbon.

I said before the tensile strength of fire-box plate may range from 55,000 to 65,000 lb. per sq. in. This tensile strength may be obtained either by having a certain carbon content or to a considerable extent by cold rolling, and the thinner the plate for the same carbon content, the greater tendency to higher tensile strength. For example, in Bulletin No. 5 of the American Welding Society that describes the tank tests made at the Bureau of Standards, the "C" tanks in Table No. 2 were made of 25 per cent carbon steel that had a tensile strength of 65,000 lb. per sq. in., while the "F, G, H, and K" tanks containing an average of about 10 per cent carbon had an average tensile strength of about 49,000 lb. per sq. in. In Table No. 3, of the same Bulletin, the tensile strength of the thinner materials was noticeably greater although their carbon content which is not given was about 12

per cent. For instance, tanks "X2, 3, and 4" had a tensile strength of about 62,500 lb. per sq. in. and there is a considerable variation in this tensile strength. This is undoubtedly due to the varying amounts of cold work.

In any structure that has none of its parts heated, advantage may be taken of this cold work in the design. That is, the strength of the material as rolled may be used as a basis for the design, but as heating removes the effect of the cold work, any strength imparted by cold work should not be considered in any structure that is heated. For instance, in flanging a boiler sheet, heat is applied and the strength of the flanged piece is not the same as before flanging. Under certain conditions, it may be greater, but usually it is weaker; exactly what happens depending upon the duration of the heat and its intensity. In the same way, steel structures that are fusion welded should be designed on the basis of the strength of the metal that has been heated if this is less than that which has not been heated. Of course, if it is greater, the strength of the sheet itself governs the design.

One very common form of riveted and welded structures is that of a pressure vessel. In designing a riveted one, if the designer wishes to take full advantage of the tensile strength of the plate, he will require test pieces from each piece going into the construction of the vessel, and by properly arranging the diameters of the rivets and their spacing and number, he can attain with a given type of joint a maximum efficiency and, therefore, a maximum strength. In production work, that is, where a large number of similar tanks are made, it is not commercially feasible to follow this practice, and he usually takes the minimum limit of tensile strength as his basis of design. For example, his specification may call for plate varying from 55,000 to 65,000 lb. tensile strength, and for safety he uses 55,000 as his design basis with whatever factor of safety and joint efficiency he may desire.

Exactly the same result is obtained by using a definite maximum working fiber stress. In the case cited, if he uses a factor of safety of 5, this fiber stress would be 11,000 lb. per sq. in., which, of course, would be multiplied by the efficiency of the joint for the design figured.

With welded joints, the first method is not applicable because the strength of the weld when made with any particular welding material cannot be varied, assuming, of course, good workmanship. For instance, the strength of the weld metal in a fusion weld when it is made with ordinary low carbon steel welding wire and of the double V type, is about 50,000 lb. per sq. in. Now if the plate be of 50,000 lb. tensile strength, the efficiency of the joint would be 100 per cent. If, however, the strength of the plate be 65,000 lb., the efficiency of the joint would be only 77 per cent. Two things, therefore, are clear—first, that the term, "efficiency of the joint," should only be used in connection with welded structures when a thorough understanding of what the term really

means is had. Second, that in testing welders, the tensile strength of the plate used must be known if fair comparisons are made, and justice is to be done to the different men.

With regard to the latter, it is obvious that a welder who makes his test welds in a 50,000 lb. plate, can by reinforcing his welds, which is usually done, break the plate; while another welder using a higher tensile strength plate may have his test pieces break in the weld. It would be quite unfair to the latter man to say that because his pieces broke in the weld his ability was inferior to that of the man whose pieces broke outside the weld.

Such a comparison would be unfair in a regular tensile test and would be equally unfair in a bend test, because with the weaker plate, the bending would occur largely outside of the weld, and a cursory examination would commend such a weld. With the higher tensile strength plate which is naturally stiff, the bending would occur more in the weld with the probable result that it would not bend to the same angle as the first one before breaking. A similar cursory examination would condemn the latter weld.

It seems clear, therefore, that the only fair basis for design in the case of welded structures is to use a maximum working fiber stress based either on the tensile strength of the plate, or on the tensile strength of the weld metal whichever is the lesser. This brings us to another important point, which although it has been brought out in the above, may be re-stated in different words to make it more clear.

Using a rather exaggerated case—a 50,000 lb. weld in a 50,000 lb. plate is just as strong as a 50,000 lb. weld in 100,000 lb. plate, although the efficiencies in the two cases are 100 per cent and 50 per cent. In the first case, theoretically, the rupture may occur in either the weld or the plate, but in the latter case, it will always occur in the weld. This shows us that there is no advantage in using plate of higher tensile strength than that of the weld metal. It also shows that there is no decrease in thickness with high tensile strength plate.

It is, of course, quite desirable that we be able to produce a weld that will be equal in strength to the highest tensile strength plate that can be obtained, and this has been done in experimental work. There is, however, the difficulty of welding high carbon plate, the carbon of which gives it its high strength, and until these difficulties are overcome by the development of proper procedure controls, we are better off to use a low carbon plate that we are sure will give perfect safety.

It has come to my attention in a number of instances in different parts of the country, that there are some people who are in doubt as to some of the details and methods of designing welded tanks and other similar structures subject to internal pressures. Of course, this does not apply to engineers familiar with such work, but for the benefit of those who are not so familiar with it, it probably would be well to say a few words about this subject. My

belief is that the double V type of weld is always superior to the single V type. There is a strong tendency in any single V weld, particularly when made with ordinary welding materials, to be imperfect at the bottom of the V. In addition to this, reinforcing the weld, that is, adding metal to one side, throws the line of resistance of the weld metal to one side of the line of application of the stress. This results, of course, in eccentric loading, and it is well known that this increases the stress at the bottom of the V to a very high point. It may be also pointed out that even if the weld be sound and entirely fused at the bottom of the V, there is a different amount of weld metal at the top of the V than at the bottom, and that the physical characteristics of a section at the top and bottom of the V are different because of the difference in characteristics between the base and weld metals. Further, my experience convinces me that the weld metal at the bottom of the V is never as good and as sound, even when thoroughly fused to the base metal, as it is in the upper part of the weld— so that as I stated before, I am thoroughly convinced that a weld of the double V type is superior to one of the single V type.

The tests of pressure vessels at the Bureau of Standards that were sponsored by the American Welding Society show that with the materials used, it was perfectly safe to use a maximum working fiber stress of 8,000 lb. per sq. in. for a double V weld, and, therefore, the Welding Society recommended that this be used as shown on Page 3 of Bulletin No. 5. The Bulletin also shows the derivation of this figure on Page 12, under the heading "Design." The average bursting strength of the regular tanks with double V welds was 50,000 lb.—using a factor of safety of 5 or a working stress of 10,000 lb. and allowing 20 per cent for irregularities in workmanship gave the figure 8,000 lb. It would certainly seem that this is not too high a figure for safety in practice. The usual formula for the strength of thin shells subjected to internal pressure is—

$$p = \frac{2t \times T}{D}$$ in which "p" equals the maximum allowable working pressure in lbs. per sq. in.

"t" equals the thickness of plate in inches.

"T" equals the maximum allowable fiber stress in lbs. per sq. in.

"D" equals the internal diameter of the shell in inches.

Barlow's formula is the same except that he used the outside diameter instead of the inside.

A thin shell is one whose thickness is small compared to its diameter. The derivation of the formula is quite simple and easily remembered. If a section of the shell one inch long be taken, evidently the total pressure on this section will be equal to "p" multiplied by the inside diameter of the shell. This tends to tear the shell apart at the ends of some diameter so that the tensile strength of the shell at both ends of the diameter would be equal

to the above bursting stress. This resistance to bursting is equal to the area of metal at both ends multiplied by the tensile strength of the material, so that we have—

$$p \times D = 2t \times T \text{ or } p = \frac{2t \times T}{D}$$

Barlow's formula evidently decreases the allowable pressure because his diameter is somewhat larger than in the ordinary formula.

The application of this formula is very simple. Supposing, for instance, we want to design a welded tank for 250 lb. pressure and 36 in. diameter.

$$250 = \frac{2t \times 8000}{36} \text{ or } t = .5625 = 9/16 \text{ in.}$$

The application of this formula to shells whose thickness is great in proportion to their diameters will not give satisfactory results, and in such cases it is probably better to use the formula of Birnie. However, it is unusual to find a case in which Barlow's formula will not make a perfectly safe structure, and as there is always a reasonable factor of safety used in designing, it is quite improbable that there is at present any real necessity for formulas other than that of Barlow.

These formulas give the strength of the longitudinal seams. Many times girth seams are used, and for tanks subjected to internal pressure, the theoretical resistance of such seams is twice that of the longitudinal seam. This is shown as follows:

The stress around the circumference is equal to the area of the shell multiplied by the internal pressure, or using the same symbols as before—

$$P = \frac{\pi D^2}{4} \times p$$

The resisting ability of the tank to rupture is, in this case, equal to the area of the metal in the shell multiplied by its tensile strength, or under the assumption that in a thin shell there is practically no difference between the inside and outside diameter, this would be equal to—

$$\pi Dt \times T$$

The bursting pressure is, of course, equal to this so that equating them we have—

$$\frac{\pi D^2}{4} \times p = \pi Dt \times T, \text{ or } p = \frac{4tT}{D}$$

Which means, the maximum allowable working pressure is twice on the girth seam what it is on the longitudinal seam.

There is, therefore, with good welding no danger from the girth seam in the welded tank even if it be of the single V type, particu-

larly as the stress on it within the yield point is to all intent and purposes pure tension, the curved shape of the shell resisting successfully any tendency toward eccentric loading.

The next point to be considered is the design of the heads. These may be any shape from flat to hemispherical. Evidently a flat head has very little resistance to internal pressure unless it is braced by tie-rods or diagonal bracing of some type. As this method of reinforcement is usually undesirable, and as it is difficult and expensive to produce heads that are hemispherical, it is customary to dish them to a radius equal to the diameter of the shell. This dished part has to be connected to the flange by a short radius.

The strength of a spherical shell is determined as follows. Using the same symbols as before, the resisting power of the metal is equal to the area of the metal at the largest diameter multiplied by its tensile strength, or

$$\pi Dt \times T, \text{ the stress is } \frac{\pi D^2}{4} \times p$$

and these are equal. This reduces to—

$$p = \frac{4tT}{D}$$

This means that the strength of a hemispherical head of the same thickness as the shell is equal to that of the girth seam, or twice that of the longitudinal seam. It is also clear from this formula that a hemispherical shell of the same thickness as the cylindrical shell, but of twice the diameter, is equal in strength to the cylindrical shell—so that by using the head having a radius equal to the diameter of the shell, it can be made of the same thickness as the shell and have the same strength.

This is the usual construction, but unfortunately it is necessary in riveted construction to have a flange extending either inside or outside of the shell so that the head can be connected to it. This small radius is, under pressure, subject to a greater stress than any other part of the tank, and when the tank begins to distort, the effect is shown by Luders' lines, that are usually indicated by the cracking of the scale by crossing diagonal lines on the knuckle. It has been found necessary in practice to limit the minimum radius of the knuckle, and this has been done by the Boiler Code Committee of the American Society of Mechanical Engineers in their Power Boiler Code, Section P-197, and in their Unfired Pressure Vessel Code, Section U-38. The precaution has also been taken in both codes of requiring a proper thickness in the head throughout—Sections P-195 and U-36.

With regard to flat heads, it is very clear that they will not stand more than a very small pressure without distorting unless they are very thick. The formulas for flat heads are entirely theoretical, and it seems to be impossible to take into account all of the variables that exist when a flat head is stressed, so that the formulas,

which are due to Grashof, and which may be found in any good engineer's handbook, give thicknesses which are greater than are found necessary in practice, but, of course, are safe. It is much better, however, and usually much cheaper, to brace the heads as spoken of before either by tie-rods or by diagonal braces, which is the common practice in boiler flue sheets. Formulas for such bracing are given in detail in both the Power Boiler Code and Unfired Pressure Vessel Code.

In the case of flat heads, it would be well to consider the strength of the weld between the shell and the head.

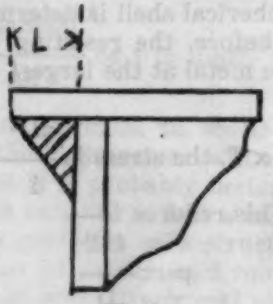

Fig. 1

Figure I shows a common construction of such a head. Evidently up to the yield point, the resistance of the head to blowing out is due to the shearing strength of the weld where it bears against the shell, or the shearing resistance of the length "L." The shearing resistance of a steel weld is approximately 40,000 lb. per sq. in., and as the pressure on the head is equal to its area multiplied by the pressure per sq. in., we have—

$$P = \frac{\pi D^2}{4} \times p$$

The resistance of the weld or its shearing strength, which we will call "S," is

$$S = \pi \times L \times 40{,}000$$

These two being equal, we have—

$$L = \frac{pD}{160{,}000}$$

If we take the same tank as we used for the previous illustration and use a factor of safety of 5, we have—

$$L = .28 \text{ in.}$$

Undoubtedly, in practice the weld would be made larger than this for welding reasons.

Therefore, as long as there is no bending stress on the weld, that is, as long as the stress is pure shear, it is quite safe to make a head of the construction shown.

Design of Welded Joints in Ship Construction*

J. W. OWENS†

Thermal Considerations and Stresses

Practically every form of welding can be advantageously used in the repair and construction of ships, provided each form is utilized for the class of work to which it is best adapted.

In general the size and complexity of a ship's structure, and the necessity for doing most of the welding on the ship subsequent to assembly requires the use of those forms in which the thermal energy can be extremely localized, and joints which permit the relief of the thermal stresses, even though the structure be fully assembled. Metal arc welding has for these reasons, and because of its extreme flexibility, been found particularly suitable for the construction of the hull and machinery foundations, while lap and tee joints are easy to assemble and have the lowest residual stresses of the various forms of joint when welded subsequent to complete assembly.

Lloyd's Register of Shipping, recognizing these basic considerations, permits the use of metal arc welding in hull construction and specifies the use of lap and tee joints. The butt joint is also permitted, but it is required to be strapped.

As automatic arc welding machines make it possible to weld the butt joint at a high rate of speed, and thereby reduce thermal stresses to a minimum, it might be possible in the future to use this joint, unstrapped, provided the carbon content of the plate be kept low, preferably below 0.15 per cent, and the joint properly reinforced with weld metal. Another basic consideration might be the deposition of weld metal of a higher tensile strength than that of the base metal, or weld metal, which has high ductility as can be secured with the hydrogen arc.

Thermit welding is, in the opinion of the author, preferable to smith welding for the construction of new stern frames, and the frames of large rudders, but its use on new construction has to date not been approved by the Classification Societies; on the other hand, both Lloyd's Register of Shipping and the American Bureau of Shipping permit its use in the repair of broken stern frames. I am also of the opinion that its use can be advantageously extended by these Societies to members subjected to torsional stress.

As gas welding is in general industrial use for the construction of tank, pipe fittings, the welding of pipe lengths together without the use of flanges, and in the manufacture of metal furniture, its application to this class of work in shipyards is considered good practice. It should be noted, however, that metal arc welding can

*To be presented at annual meeting, A. W. S., April, 1926.
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TABLE "A"

Size of Assembly Holes, Distance from Edge of Plate or Strap, and Width of Lap

NOTE:—In cases when weight, as determined by width of lap, is important, holes can be drilled and a smaller size of assembly bolt used.

PLATE		ASSEMBLY HOLE						WIDTH OF LAP (Inches)	
Weight (Lbs. per ft.)	Thickness (Inches)	Size (Inches)	Distance of Hole from Edge of Plate or Strap (Inches)		Distance of Center of Hole from Edge of Plate or Strap (Inches)		Punched or Drilled	Flat Surfaces	Curved Surfaces
			Flat Surfaces	Curved Surfaces	Flat Surfaces	Curved Surfaces			
–10.0	–.24	5/8	5/8	5/8	5/8	11/16	Punched	1¼	1⅜
10.1–13.6	.26– .34	11/16	5/8	5/8	11/16	3/4	Punched	1⅜	1½
13.7–19.6	.36– .48	13/16	3/4	5/8	3/4	15/16	Punched	1½	1⅝
19.7–28.7	.50– .70	15/16	7/8	7/8	7/8	1 1/16	Punched	1¾	1⅞
28.8–34.0	.72– .84	1 1/16	7/8	1	1	1 1/16	Punched	2	2⅛
34.1–37.7	.86– .92	1 1/16	7/8	1	1	1 1/16	Drilled	2⅛	2⅛
		1 3/16	7/8	1	1 1/16	1 1/16	Punched	2⅛	2¼
37.8–40.0	.94– .98	1 3/16	7/8	1	1	1 1/16	Drilled	2	2⅛
		1 5/16	7/8	1	1 1/16	1 1/16	Punched	2¼	2⅜
40.1–47.0	1. 0–1.16	1 3/16	1	1	1 1/16	1 1/16	Drilled	2⅛	2⅛
		1 5/16	1	1	1 1/16	1¼	Punched	2⅜	2½

also be used for the majority of this work, and as there are no basic limitations to the use of either form for this work, selection may be left to the individual shipyard. The butt joint is preferred for gas welding and can be used on this class of work for both gas and metal arc welding, as the thermal stresses are relieved by the contour of individual jobs and warping prevented by the use of jigs. Gas welding is used almost exclusively for the welding of all the non-ferrous metals and cast iron when readily preheated. In the Navy thousands of dollars are saved annually in the repair of broken manganese bronze propeller blades and the rebuilding up of cast iron pistons with a bronze filler rod.

TABLE "B"

Maximum Spacing of Assembly Holes

PLATE		Maximum Spacing of Assembly Holes (Inches)	
Weight (Lbs. per ft.)	Thickness (Inches)	Flat Surfaces	Curved Surfaces
-13.6	-0.34	36	30
13.7-19.6	0.36-0.48	30	24
19.7-47.0	0.50-1.16	24	18

TABLE "C"

Safe Load Per Linear Inch of Continuous Fillet Weld

Thickness of Base Metal (Inches)	Depth of Throat (Inches)	Safe load in pounds per linear inch of a full continuous fillet weld. Throat x 9000 lbs.
3/16	0.177	1,593
1/4	.266	2,394
5/16	.355	3,195
3/8	.529	4,761
1	.702	6,318
1 1/4	.882	7,938
1 1/2	1.062	9,558
1 3/4	1.237	11,133
2	1.415	12,735

Electric resistance welding, although used extensively in the manufacture of metal furniture for Naval ships and for tanks of the lighter gages of metal, has the inherent limitation of restricted portability. It is probable, therefore, that this limitation will be a serious handicap to its extensive use in the construction of the hull of ships.

Design and Assembly

Ship structures intended to be jointed together by welding instead of riveting should be specially designed with that end in view, in order to save the maximum weight without sacrificing strength, to permit as much welding as possible to be performed in the shop, and to reduce overhead welding to a minimum.

The width of lap joints, when metal arc welded, may be reduced to the thickness of the plate; however, assembly is, in general, greatly facilitated by the use of bolts through the faying surfaces,

Assembly holes should preferably be punched from the faying side, as the burred plate edge prevents a close alignment of plate surfaces. For size of assembly holes, distance from edge of plate or strap, and width of lap, see Table A.

The number of assembly holes should be the minimum required for assembly and consideration given the punching of additional holes with the gas torch, carbon or metal arcs when needed. Bolts may be temporarily tack welded adjacent to the joint in lieu of

TABLE "D"

Linear Inches of Continuous Fillet Weld Required to Develop Full Strength of One Rivet in Single and Double Shear

Tensile strength of base metal per sq. in.	60,000 lb.
Tensile strength of weld metal per sq. in.	36,000 lb.
Shearing value of rivets per sq. in.—single shear	50,000 lb.
Shearing value of rivets per sq. in.—double shear (1.8 × 50,000) =	90,000 lb.
Bearing value of plate per sq. in.	120,000 lb.

Note:

1. All values given are ultimate and any factor of safety used would not affect the comparison.
2. Linear inches of weld metal required to develop full shearing strength of one rivet is based on the value which determines the strength of the connection.
3. For linear inches of light continuous welding required to develop a relative strength, multiply columns 4 and 6 by 2.
4. One linear inch of base metal requires 2.357 linear inches of a full continuous fillet weld or 1.666 linear inches of a reinforced continuous fillet weld to develop full strength of the base metal.

Thickness of Base Metal (Inches)	Size of Rivets (Inches)	Ultimate Strength of Full Continuous Fillet Weld per Linear Inch	Linear inches of continuous Fillet weld required to develop full strength of one rivet			
			Single Shear		Double Shear	
			Full Weld	Reinforced Weld	Full Weld	Reinforced Weld
1	2	3	4	5	6	7
¼	⅝	6,364	2.91	2.06	*2.94	*2.08
⅜	⅞	9,546	2.19	1.55	*3.53	*2.50
½	⅞	12,728	2.70	1.91	*4.11	*2.91
⅝	⅞	15,910	2.17	1.54	3.90	1.77
¾	1	19,092	2.33	1.65	4.20	1.97
⅞	1	22,274	1.93	1.37	3.60	2.55
1	1⅛	25,456	2.17	1.54	3.91	1.77

*Bearing value determines strength.

punched holes, and the joint surfaces pulled together by clips. Suitable magnetic clamping devices may also be developed with the extension of the science. On completion of welding, assembly holes can be closed by the insertion of a rivet burr in the hole and the welding of one or both sides, or the driving of a rivet. For maximum spacing of assembly holes, see Table B.

In the design of joints, it is recommended that all calculations for tensile strength and shear be based on the throat section of the weld, 36,000 lb. per sq. in. being taken on the ultimate tensile strength and shearing value of the weld metal, and 32,000 lb. per sq. in. as the elastic limit in compression. See Tables C and D.

The full fillet weld should be considered the standard metal arc weld and employed wherever possible. The light weld may be used

in securing tightness in welded joints, or in lieu of mechanical calking in riveted joints, but it should not be considered in the determination of the strength of the joint. The reinforced fillet should be employed wherever it is possible to use only one fillet to secure maximum strength or tightness.

As strength welds can be made either continuous or intermittent, the strength of the joint desired will be primarily dependent on the continuity and weight of the weld. In general, welds, unless otherwise specified, should be made continuous.

Tack welds, useful in assembly, should not be considered as contributing to the strength of the joint.

TABLE "E"

Current Values and Sizes of Bare Electrodes Recommended for Various Thicknesses of Base Metal

Thickness of Base Metal (Inches)	Size Electrode (Inches)	Amperes
1/16	1/16	80–125
	3/32	125–160
1/8	3/32	125–160
	1/8	160–180
3/16	1/8	180–200
1/4	1/8	200–225
5/16	1/8	180–225
	1/4	200–260
3/8	1/8	180–225
	1/4	200–260
1/2	1/8	180–225
	1/4	200–260
5/8	1/8	180–225
	1/4	200–260
3/4	1/8	180–225
	1/4	200–260
1	1/8	180–225
	1/4	200–260

Technic

All metal arc welds should in general be made in one layer; however, the use of multiple layers is frequently necessary due to the thickness of the metal weld, the weight of the weld, and tightness required. If gas or oil tightness is necessary, a continuous fillet weld should be made on each edge of the lap of both sides of the tee joint, however, when only one fillet weld is possible, and oil or gas tightness is required, it should be made in at least two layers.

Due to the variety of gas torches on the market, it is impossible to specify the size of the tip and gas pressures to be used for the various thickness of metal. Reliance will therefore have to be placed on the recommendations of the manufacturer of the torch

used. The current values and sizes of electrodes given in Table E are recommended for use with bare low carbon steel electrodes and direct current.

Materials

Ship plate has in general a carbon content of 0.25 per cent and is found satisfactory for welding. However, a reduction in the carbon content to 0.15 per cent would be preferable. Welding in ship construction is generally satisfactory for joining medium, soft or flange, and common steels, wrought iron, and castings and forgings of ferrous metals. In Naval vessels, welding for strength purposes should not be used on armor plate, special treatment, nor high tensile steel, due to the embrittling effect of the fusion heat on this material. In so far as the welding of the non-ferrous metals and cast iron is concerned, standard industrial practice can be adhered to.

Tests

On all piping systems, tanks and watertight bulkheads, it is desirable to adhere to existing tests for riveted joints, with or without the addition of the hammer blow test.

As the testing of each joint of the ship's structure is impracticable, reliance will have to be placed on properly designed joints, competent supervision, certification of all welders and the use of carefully selected filler material. In this connection it might be of interest to mention that our company is now taking steps to certify all of the welders and to issue standard practice sheets covering design and technic.

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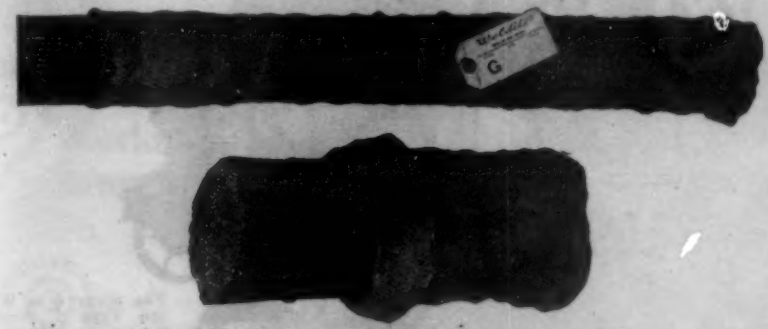

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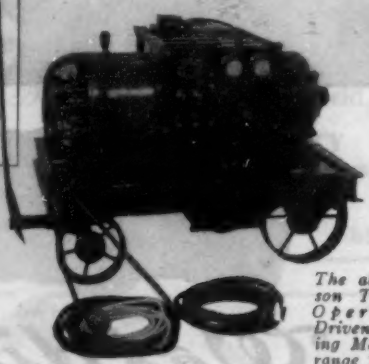

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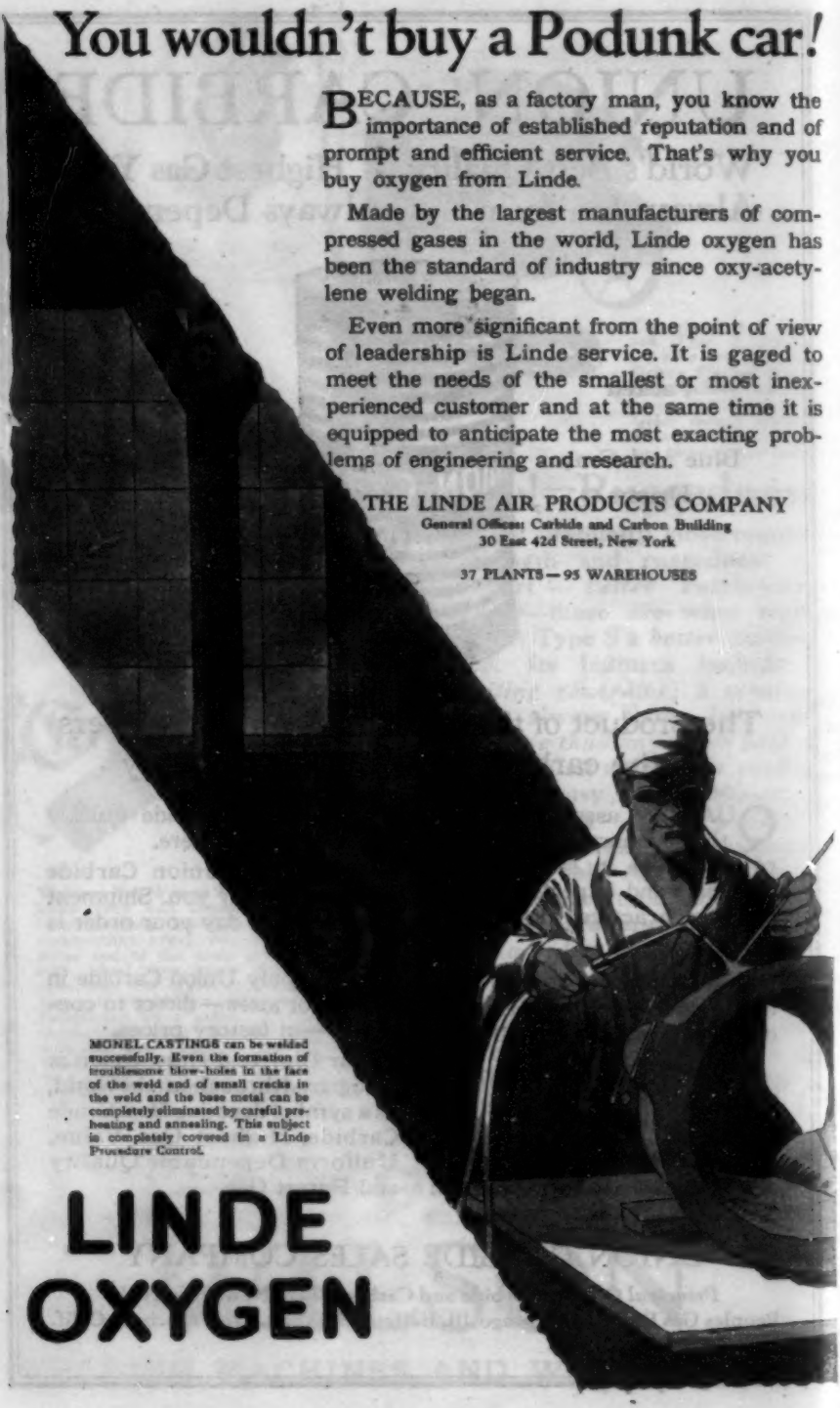

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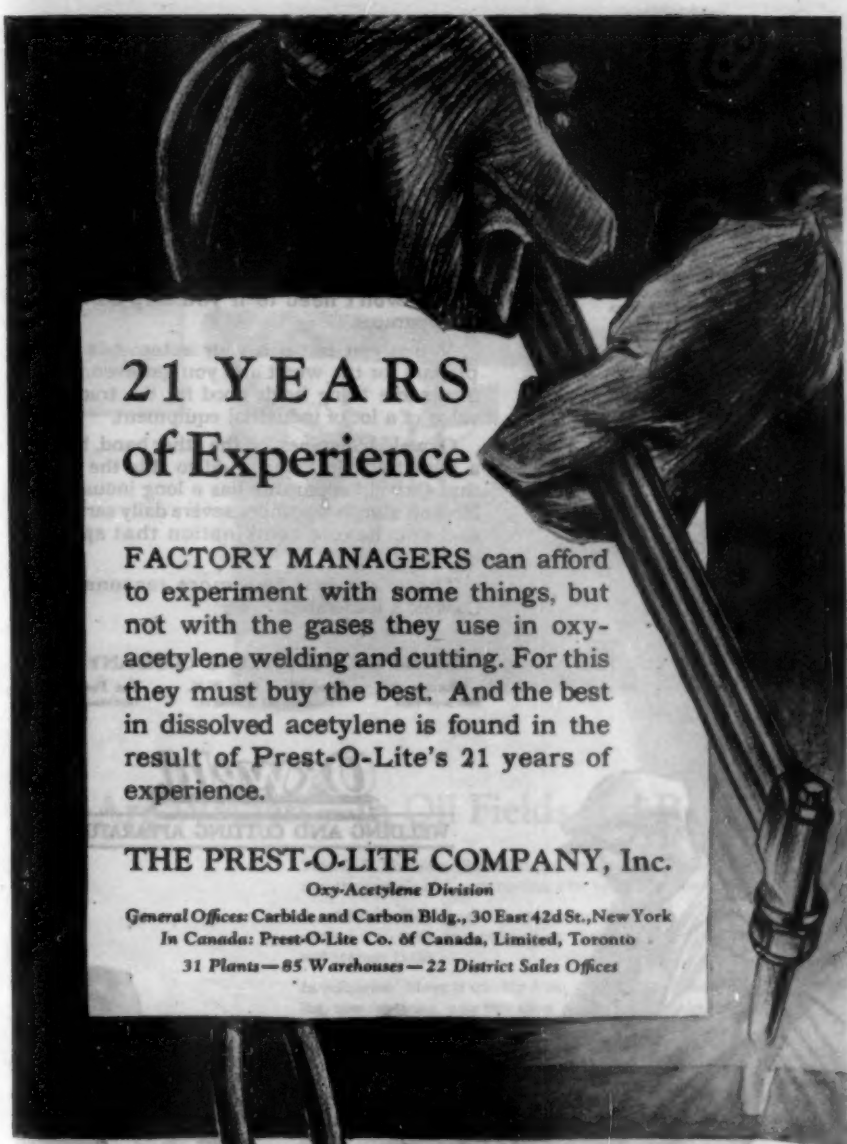
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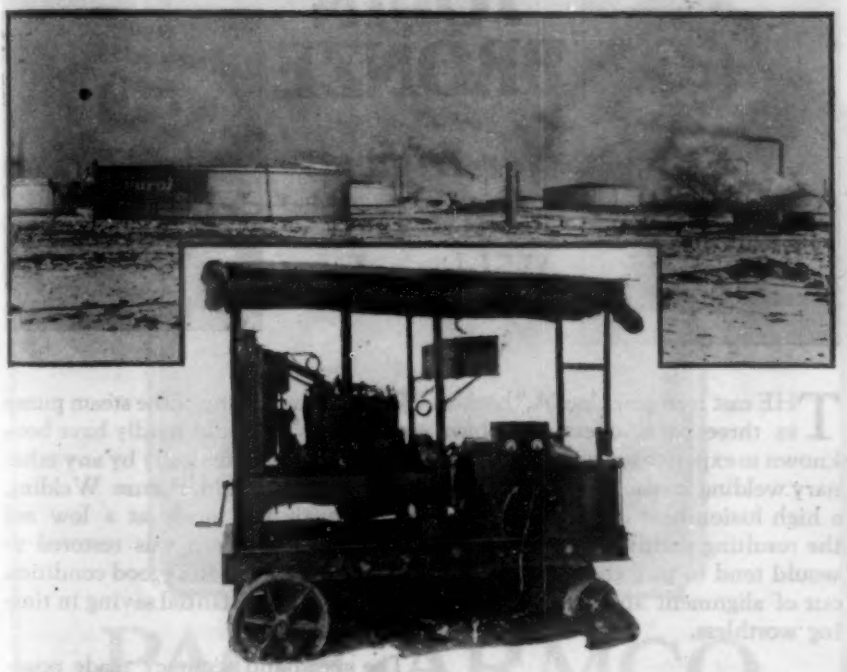

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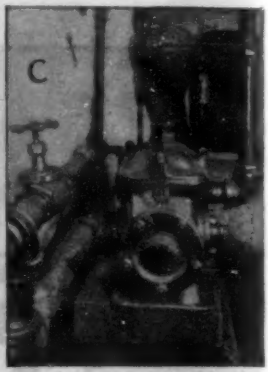

THE cast iron gear case "A," broken in three parts, offers a problem known to experienced welders. Ordinary welding methods would require a high fusion heat for such a job, and the resulting shrinkage of the casting would tend to pull the bearing holes out of alignment and make the casting worthless.

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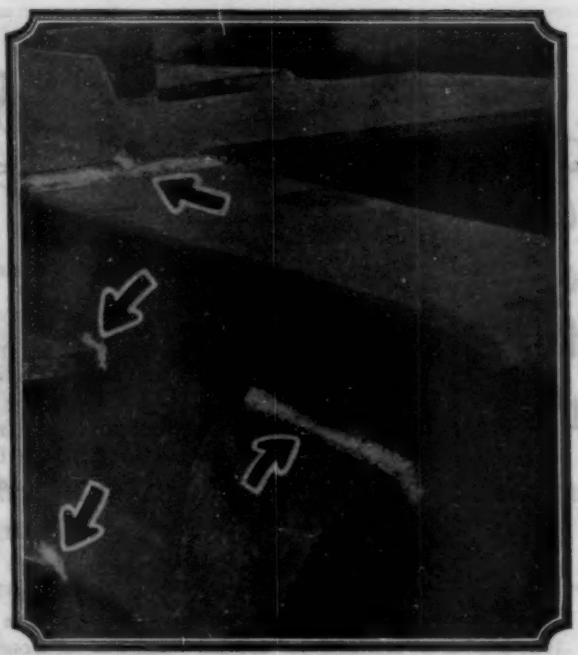

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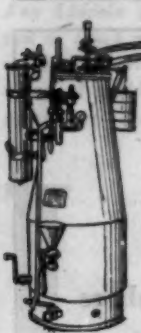

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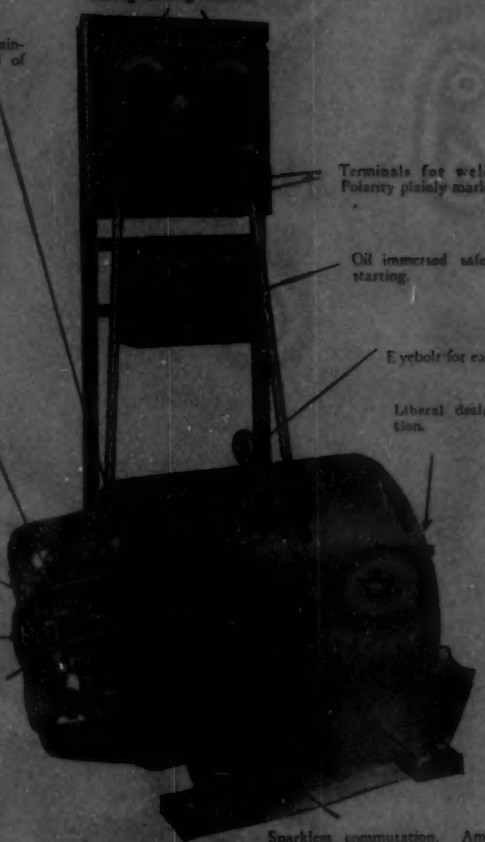
Voltmeter and ammeter furnished for indicating polarity and current. Meters are not necessary for regulating welding current.
Self exciting. No exciter to maintain. No accidental reversal of polarity.
Terminals for welding leads. Polarity plainly marked.
Oil immersed safety switch for starting.
Indicator plate and pointer shows settings and current values. Wide range of current regulation 50 to 300 amperes in an infinite number of steps.
Eyebolt for easy handling
Liberal design. Rugged Construction.
Accurate and convenient regulation of welding current to value desired. Open circuit voltage practically constant throughout entire range
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